[illegible] IGUANODON, RESTORED BY JOHN MARTIN ESQ K.L.

THE

# WONDERS OF GEOLOGY;

BY

GIDEON ALGERNON MANTELL, LL.D. F.R.S.

AUTHOR OF

THE GEOLOGY OF THE SOUTH EAST OF ENGLAND,

ETC. ETC.

*Silver Coins of Edward the First, in ironstone.—Page 67.*

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"To the natural philosopher there is no natural object unimportant or trifling: from the least of nature's works he may learn the greatest lessons."—SIR J. F. W. HERSCHEL.

"We know not a millionth part of the wonders of this beautiful world."—LEIGH HUNT.

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IN TWO VOLUMES.

VOL. I.

*THIRD EDITION.*

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1839.

TO

THE RIGHT HONOURABLE

GEORGE EARL OF MUNSTER,

F. R. S. F. G. S.

&c. &c. &c.

AS A TESTIMONY OF THE HIGHEST RESPECT AND REGARD,

AND IN GRATEFUL ACKNOWLEDGMENT

OF HIS LORDSHIP'S

STRENUOUS ENDEAVOURS TO PREVENT THE DISPERSION

OF THE AUTHOR'S COLLECTION,

These Lectures are Inscribed,

BY HIS LORDSHIP'S

MOST FAITHFUL AND OBLIGED SERVANT,

GIDEON ALGERNON MANTELL.

CRESCENT LODGE, CLAPHAM COMMON,
*May* 1, 1839.

## DESCRIPTION OF THE FRONTISPIECE.

*The Country of the Iguanodon, restored from the Geological Discoveries of the Author.* *By* JOHN MARTIN, Esq. K.L.

The mode of induction by which the geologist and comparative anatomist are enabled to ascertain the form and structure of animals and plants which no longer exist on the face of the earth, and even the nature of the countries which they inhabited, are explained in the following pages. The researches of the Author in the wealden formation (p. 344) of the south-east of England, furnished the materials from which the eminent painter of "BELSHAZZAR'S FEAST," composed the striking picture that forms so splendid an embellishment to this Work.

The data upon which the restorations are founded are described in the Fourth Lecture (see p. 404). The picture represents a country clothed with a tropical vegetation, peopled by reptiles of colossal magnitude, and traversed by a river, which is seen to empty itself into the sea, in the distance. Oolitic rocks (p. 361) form the heights and cliffs with which the landscape is diversified. The vegetation consists of the trees and plants whose fossil remains have been discovered in Tilgate Forest (p. 369); namely, palms, arborescent ferns, clathrariæ, and coniferous tree; while the lesser plants, as the cycadeæ, (p. 365) and ferns (pp. 369—371), are distributed over the foreground.

The reptiles comprise the iguanodon (p. 389), hylæosaurus (p. 401), megalosaurus (p. 389), crocodiles (p. 385), and turtles (p. 384). An iguanodon attacked by a megalosaurus and crocodile, constitutes the principal group; in the middle distance an iguanodon and hylæosaurus are preparing for an encounter; a solitary pterodactyle, or flying reptile (p. 403), with its wings partly expanded, forms a conspicuous object in the foreground; while turtles are seen crawling on the banks of the river. Ammonites and other shells of the Portland oolite, which is the foundation rock of the country, are strewn on the shore. Wading birds allied to the heron (p. 403), should have been introduced to render the fauna of the iguanodon country complete.

The vigour and beauty of this successful conception of the distinguished artist are equalled by the fidelity of its details.

# PREFACE.

In preparing the first edition of this Work for the press, I was greatly assisted by the kindness and zeal of my friend, G. F. Richardson, Esq.* whose ability as a reporter enabled him to furnish me with copious notes of the Lectures which I delivered at Brighton, in an unsuccessful attempt to establish a County Museum, and Scientific Institution in that town. Those notes were the ground-work of the unpretending volumes which, under the title of "The Wonders of Geology," have met with so favourable a reeeption.

The former publication, consisting of two thousand copies, having been disposed of in the course of a few months, a new edition is required, and I have therefore carefully revised

* Of the British Museum.

the Work, and made such corrections and additions as the leisure moments which my professional engagements have allowed me, would permit.

The additional illustrations are both numerous and important, and I trust will be found to enhance the interest of these volumes, without having materially increased their size or price.

My geological collection, consisting of upwards of twenty thousand specimens, from which the subjects for the illustration of the Lectures were selected, was, at the period of the former editions, exhibited at Brighton by the Sussex Literary Institution, as the "*Mantellian Museum*." At that time I had every reason to believe that my collection would be permanently established in Sussex, and serve as the foundation for a County Museum. In that expectation I have, however, been utterly disappointed; for although I would willingly have made any pecuniary sacrifice, to accomplish what appeared to me so desirable an object, yet after the death of my noble and lamented friend, the late Earl of Egremont, the munificent patron of the Institution, the proposed measure was abandoned, and even opposed by many of its former supporters. I have therefore, in compliance with the wishes of my scientific friends, disposed of my entire collection to the Trustees of the British Museum.

But although the main object of my labours has thus been frustrated, and that collection, which would have been of tenfold importance if located in the district from whence it was derived, and whose physical structure it was designed to illustrate, is now broken up, and will be dispersed through the cabinets of our National Institution, yet the most interesting specimens are so unique, and so strikingly distinct from any others hitherto obtained, that they may be referred to with facility, when the gallery of organic remains in the British Museum shall be finally arranged.

I avail myself of this means to record the deep sense of obligation I feel to many excellent friends, for their strenuous and unremitting exertions to prevent the dispersion of my Museum, and establish it on a permanent basis in my native county. And although their efforts have proved unavailing, a time will assuredly come, when their endeavours to promote a taste for scientific knowledge among the intelligent inhabitants of Sussex, and to direct attention to the investigation of its physical phenomena, will be properly appreciated, and the failure of their attempt to secure to the county a collection so rich in its peculiar fossil and mineral productions, be remembered with regret.

Should Providence allot me life and health, I purpose adding another volume to this Work, under the title of "First Lessons, or an Introduction to The Wonders of Geology;" being the substance of a series of Lectures, designed for persons wholly unacquainted with the nature of geological investigations.

G. A. M.

Crescent Lodge, Clapham Common,
*May* 1, 1839.

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# WONDERS OF GEOLOGY.

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## LECTURE I.

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1. Introductory remarks. — It has been observed by a distinguished divine,* that in order to obtain a proper sense of the interest and importance of any science, and of the objects which it embraces, nothing more is necessary than the intent and persevering study of them; and that such is the consummate perfection of all the works of the Creator, that every inquirer will discover a surpassing worth, and grace, and dignity, in that especial department of knowledge to which he may peculiarly devote his attention. Whatever walk of philosophy he may enter, that will appear to him the path which is the most enriched by all that is fitted to captivate the intellect, and to excite the imagination. Yet before we can attain that elevation from which we may look down upon and comprehend the mysteries of the natural world, our way must be steep and toilsome, and we must learn to read the records of creation in a strange language. But when this knowledge is once acquired it becomes a mighty instrument of thought, enables us to link together the phenomena of past and future times, and gives

* Professor Sedgwick.

the mind a domination over many parts of the natural world, by teaching it to comprehend the laws by which the Creator has ordained that the actions of material things shall be governed.

2. Importance of geology.—In the whole circle of the sciences, there is perhaps none that more strikingly illustrates the force and truth of these remarks, than Geology; none which offers to its votaries rewards so rich, so wondrous and inexhaustible. In the shapeless pebble that we tread upon, in the rude mass of rock or clay, the uninstructed eye would in vain seek for novelty or beauty; like the adventurer in Eastern fable, the inquirer finds the cavern closed to his entrance, and the rock refusing to give up the treasures entombed within its stony sepulchre, till the talisman is obtained that can dissolve the enchantment, and unfold the marvellous secrets which have so long lain hidden.

3. Nature of geology.—To the mind which is unacquainted with the nature and results of geological inquiries, and which has been led to believe that the globe we inhabit is in the state in which it was first created, and that with the exception of the effects of a general deluge, its surface has undergone no material change, many of the facts to be noticed in the course of these lectures may appear almost incredible, and the inferences deduced from their investigation be considered as the vagaries of the imagination rather

than the legitimate inferences of sound philosophy. If, therefore, it be absolutely neeessary, as it unquestionably is, that in the pursuit of knowledge of any kind, before even expcrience ean bc employed with advantage, we must dismiss from our minds all prejudiees, from whatsoever souree they may arise, this mental purifieation becomes the more indispensable in a science like Geology, in whieh we meet at the very threshold with faets so novel and astounding; teaehing us, that although man and other living things be, as it were, but the creation of yesterday, the earth has teemed with numberless forms of animal and vegetable life, myriads of ages ere the existenee of the human raee.

Geology may be termed the physical history of the earth,—it eomprehends the investigation of its strueture, and the eharaeters and eauses of the various changes which have taken plaee in the organic and inorganic kingdoms of nature. It has been emphatieally called, by one of our most eminent philosophers, the sister seienee of Astronomy. But, relating as it does to the history of the past, and carrying us baek, by the eareful examination of the relies of former ages, to periods so remote as to startle all our preeonceived opinions of the age of our globe, the fate of its early eultivators has resembled that of the immortal Galileo and the astronomers of his time; and for a similar reason, namely, the supposed diserepancy between the discoveries and inferenees of seienee, and the Mosaie cosmogony.

4. Harmony between revelation and geology.—There was a time when every geologist was required to defend himself against imputations of this kind, and I deeply regret to find that there still exists in the minds of many well-meaning persons a prejudice against the study of Geology, from a mistaken apprehension, lest it should weaken our belief in the revealed word of God; for they assume that a discrepancy must exist between the results of geological inquiries and the Mosaic account of the creation of the world. But, convinced as I am of the utter impossibility that there ever can be any collision between the purest piety and sound philosophy, and that these prejudices have been created and perpetuated by authors, who, falsely styling themselves geologists, have mixed up their own vague and erroneous notions with the history of the earth as given by the inspired writer, attempting, with the presumption of ignorance, to account for that which lies beyond the reach of human investigation, and to explain it by evidence equally misapprehended and misapplied,—I would most unequivocally assert that a just view of the nature and limits of geological science warrants no such reproach. Abandoning all attempts to explain the inexplicable, or to reconcile the irreconcilable, it confines itself to its legitimate purpose of accumulating and investigating facts, of pointing out analogies, and indicating the inferences to which they lead; "this is far different from that pre-

sumption which would fain prove the truth of Scripture by physical evidence, or the weakness that would found a system of natural philosophy on the inspired record." Nothing is more unwarrantable than attempts to identify theories in science with particular interpretations of the sacred text; and the caution of Lord Bacon, uttered a century and a half before geology even had a name, cannot be too often repeated. "Let no man," said he, "upon a weak conceit of sobriety, or an ill-applied moderation, think or maintain that a man can search too far, or be too well studied in the book of God's word, or the book of God's works—divinity or philosophy: but rather let men endeavour an endless progress or proficiency in both; only let them beware that they apply both to charity and not to arrogance—to use and not to ostentation; and again, *that they do not unwisely mingle or confound these learnings together*." So deeply impressed have I been with the necessity of strictly obeying this admonition, that in all my written or oral discussions on geology I have, on this subject, invariably confined myself to a statement of the opinions of several eminent philosophers and divines, in the hope that the example of men, alike distinguished for their piety and learning, cultivating with ardour this fascinating department of natural science, and stating their conviction of its high importance and beneficial influence upon the mind, would be a sufficient and direct reply to the absurd and unfounded charges brought against geology. On the present occasion, I shall content myself with the following extract from the sermons of the present Bishop of London: "As we are not called upon by Scripture to admit, so neither are we required to deny the supposition, that *the matter without form, and void, out of which this globe was framed, may have consisted of the wrecks and relics of more ancient worlds, created and destroyed by the same Almighty Power which called our world into being, and will one day cause it to pass away.*"*

Thus, while the Bible reveals to us the moral history and destiny of our race, and instructs us that man and the existing races of living things have been placed but a few thousand years upon the earth, the physical monuments of our globe bear witness to the same truth; and as astronomy unfolds to us innumerable worlds, not spoken of in the sacred records, geology in like manner proves, not by arguments drawn from analogy, but by incontrovertible physical evidence, that there were former conditions of our planet, separated from each other by vast intervals of time, during which this world was teeming with life, ere the creation of man and the animals which are his cotemporaries.

5. Extent of geological epochs.—At the first step we take in geological inquiries, we are

* Sermons, by Dr. Charles James Blomfield, Bishop of London. 8vo. 1829.

struck with the immense periods of time which the phenomena presented to our view must have required for their production, and the incessant changes which appear to have been going on in the natural world: but we must remember that time and change are great only with reference to the faculties of the beings which note them. The insect of a day, contrasting its ephemeral life with that of the flowers on which it rests, would attribute an unchanging permanence to the most evanescent of vegetable forms; while the flowers, the trees, and the forests would ascribe an endless duration to the soil on which they grow: and thus, uninstructed man, comparing his transient earthly existence with the solid framework of the world he inhabits, deems the hills and mountains around him coeval with the globe itself. But with the enlargement and cultivation of his mental powers, man takes a more just, comprehensive, and enlightened view of the wonderful scheme of creation; and while in his ignorance he imagined that the duration of the globe was to be measured by his own brief span, and arrogantly deemed himself alone the object of the Almighty's care, and that all things were created for his pleasures and necessities, he now becomes conscious of his own dependence, and entertains more correct ideas of the mercy, wisdom, and goodness of the Creator. And while exercising his high privilege of being alone capable of contemplating and understanding the wonders of the natural world, he learns that most important of all lessons—to doubt the evidence of his senses, until confirmed by cautious and patient observation.

6. Object of the lectures.—With these introductory remarks I proceed to the consideration of the subjects selected for the present discourse. And here I may observe, that, from the magnitude and diversity of the objects embraced by geology, it is scarcely possible to offer, in the space assigned to a course of popular lectures, even an epitome of the wonders which modern researches have brought to light. This consideration therefore must be my apology for the concise manner in which many interesting facts may perhaps be noticed; and I would beg of you to consider that lectures of this kind are intended to excite, rather than to satisfy, a rational curiosity; that they are designed to promote a taste for philosophical pursuits, but cannot supersede the necessity of study and of personal investigation.

7. Physical structure of the earth.—The globe we inhabit may be described as a planetary orb of a few thousand miles in circumference, and of a spheroidal shape; its figure being such as a body in a fluid state, and made to rotate on its axis, would assume. Its mean density is five times greater than that of water, the interior being double that of the solid superficial crust: the internal part of the earth, if cavernous, must therefore be composed of very dense materials. Its surface is

computed to contain 190 millions of square miles, of which three-fifths are covered by seas, and another large proportion by vast bodies of fresh water, by polar ice and eternal snows; so that taking into consideration sterile tracts, morasses, &c., scarcely more than one-fifth of the surface of the globe is fit for the habitation of man and terrestrial animals.* The area of the Pacific Ocean alone, is estimated as equal to the entire surface of the dry land. The distribution of the land is exceedingly irregular, the greater proportion being situated in the northern hemisphere,

Tab. 1.—The earth as seen from the moon.†

as a reference to a terrestrial globe, or a map of the world, will clearly demonstrate.

* Bakewell's Geology. † De la Beche.

In a geological point of view, dry land may be considered as so much of the crust of the earth as is now above the level of the water, beneath which it may again disappear. From accurate calculations it is proved that the present land might be distributed over the bed of the ocean, in such manner that the surface of the globe would present an uninterrupted sheet of water. Thus we perceive that every imaginable distribution of land and water may take place; and consequently that every variety of organic life may find at different periods suitable abodes.

8. Geographical distribution of animals.—The investigation of the laws which govern the geographical distribution of animals and vegetables is highly interesting; but as my limits compel me to be brief, I must refer you to the third volume of Mr. Lyell's "Principles of Geology," for more ample details. It will be sufficient for our present purpose to state, that although it might have been expected that, all other circumstances being equal, the same animals and plants would have been found in places of like climate and temperature, this identity of distribution does not exist. When America was first discovered, the indigenous quadrupeds were all dissimilar to those of the old world. The elephant, rhinoceros, hippopotamus, giraffe, camel, horse, buffalo, lion, tiger, &c. were not met with on the new continent; while the American species of mammalia, as the llama, jaguar, paca, coati, sloth, &c.

were unknown in the old. New Holland contains, as is well known, a most singular assemblage of mammalia, consisting of more than forty species of marsupial animals, of which the kangaroo is a familiar example. The islands of the Pacific Ocean possess no quadrupeds, except hogs, dogs, rats, and a few bats.

The distribution of vegetable life, although perhaps more arbitrarily fixed by temperature and by local influences than that of animals, presents many anomalies. From numerous observations, however, it appears that vegetable creation took place in different centres, each having been the focus of a peculiar genus or species; for many plants have a local existence, and vegetate naturally in one district alone; thus the cedar of Lebanon is indigenous on that mountain, and does not grow spontaneously in any other part of the world. It is also ascertained that certain great divisions of the vegetable kingdom are distributed over certain regions: we shall have occasion to refer to this subject in the lecture devoted to the consideration of Fossil Botany.

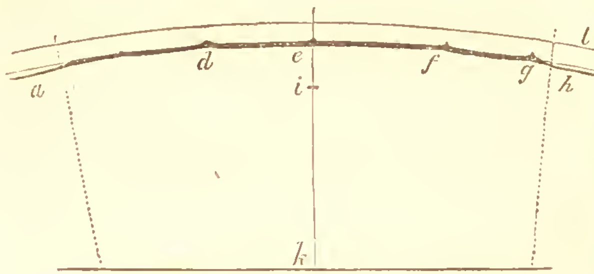
9. TEMPERATURE OF THE EARTH.—The temperature of the surface of the globe depends on the action of solar light and heat; hence the difference of the seasons, and climates of various latitudes; but there are many causes which modify the distribution of the sun's influence, and produce great local variations: under equal circumstances, however, the temperature is found progressively to

diminish from the equator to the poles. There is also an internal source of heat, the cause of which has not yet been determined, but is probably connected with the original constitution of our planet. It has been ascertained, by careful experiments, that below the depth to which the solar heat can penetrate, there is an invariable increase of temperature, amounting to 1° of Fahrenheit for every fifteen yards : so that it is possible that at the depth of 100 miles beneath the surface of the earth, even the least fusible mineral masses may be in a state of incandescence.

10. Nature of the crust of the globe.—The greatest thickness of the superficial crust of the globe, that is, *of the mass of solid materials which the ingenuity of man has been able to examine*, from the highest mountain peaks to the greatest natural or artificial depths, is estimated at about ten miles. As the earth is nearly eight thousand miles in diameter, the entire series of strata hitherto explored is, therefore, but very insignificant compared with the magnitude of the globe ; bearing about the same relative proportion, as the thickness of this paper, to an artificial sphere a foot in diameter ; the inequalities and crevices in the varnish of such an instrument would be equal in proportionate size to the highest mountains and deepest valleys. In the following diagram,*

* From the Penny Cyclopædia.

the relative proportions of the crust of the earth, and the inequalities of its surface, as compared with the mass of our planet, are attempted to be shown.*




TAB. 2.—DIAGRAM TO ILLUSTRATE THE PROPORTIONATE THICKNESS OF THE CRUST OF THE EARTH.

The line from *e* to *k* represents a depth of 500 miles; to the point *i*, a depth of 100 miles; to the line *l*, forty-five miles above the surface, the supposed limit of the earth's atmosphere; and the dark line, a thickness of ten miles, the estimated depth of the crust of the earth. The points *d*, *e*, *f*, *g*, indicate the altitude of the highest mountains in the world;† the depth of the sea is shown by the line

* To preserve as far as possible the language and spirit of the original lectures, the references to the diagrams and specimens are retained. The Author's collection is now removed from Brighton, and deposited in the British Museum.

† The highest peak of the Alps, and of Europe, is Mont Blanc, which is 15,660 feet above the level of the sea—of the Andes, Chimborazo, which is 21,425 feet—and of the Himalayas, Dhwalagiri, estimated at 28,000 feet, being more than five miles of perpendicular altitude.

*a*, *b*, at the extremities of the arc. As a thickness of 100 miles so far exceeds that of the whole of the strata that are accessible to human observation, we cannot doubt that disturbance of the earth's surface, even to ten times the depth of those which come within the scope of geological inquiry, may take place, without in any sensible degree affecting the entire mass of the globe.* If these facts be duly considered, the mind will be prepared to receive one of the most startling propositions in modern geology—namely, that the highest mountains have once been the bed of the sea, and have been raised to their present situations by subterranean agency,—some slowly, others suddenly, but all, geologically speaking, at a comparatively recent period.

* Mr. Fairholme suggests the following ingenious method to convey a general idea of the relative magnitude of the inequalities of the earth's surface. If we form a scale on the sand of the sea-shore in the proportion of an inch to a mile, we shall have a circle of 8000 inches, or 222 yards in diameter, which, when marked out with small stakes, appears a very large area. Placing ourselves upon any part of this circumference, we have an opportunity of taking a just, though microscopic, view of the surface. The highest mountains in the world would be represented by a little ridge five inches high; the profound abyss of the ocean by a groove of the same depth; while the medium inequality of sea and land would not exceed one inch. To form an idea of smaller objects, we must examine an inch scale, finely graduated, by the aid of a microscope, and we shall then find that the tallest man would be about the 880th part of an inch in height—the size of the smallest animalcule observed in fluids.

11. COMPOSITION OF THE ROCKS AND STRATA.—The superficial crust of the globe is composed of numerous layers and masses of earthy substances, of which combinations of iron, lime, and silex, or flint, constitute a large proportion; the latter forming forty-five per cent. of the whole. Those strata which have been deposited the latest, bear evident marks of mechanical origin, and are the water-worn ruins of older rocks; as we descend, materials of a denser character appear, which also exhibit proofs of having been subject to the action of water; but when we arrive at the lowermost in the scale, a crystalline structure generally prevails; and while in the newer strata, trees, plants, shells, and other remains of animals and vegetables are found in profusion, in the most ancient rocks all traces of organic forms are absent.

12. CLASSIFICATION OF ROCKS.—In the infancy of the science these remarkable facts gave rise to an ingenious theory, which, however, from being founded on insufficient data, has proved untenable. Still it may be convenient to notice the hypothesis, since the terms employed are still retained in the nomenclature of geology. Agreeably to this theory, the mineral masses of which the crust of the earth is composed, are separated into three groups.

13. PRIMARY ROCKS.—1st. *The Primitive* (now called *Primary*) *Rocks;* such as granite, sienite, porphyry, &c.: these are of a crystalline structure,

and have evidently been reduced to their present state by igneous agency. They are the lowermost rocks, and constitute the foundation, on which all the newer strata have been deposited; they also attain the highest elevations on the surface of the globe. They were termed primitive, because it was inferred, from the entire absence of organic remains, that they had been formed before the creation of animals and vegetables; but it is now ascertained that granite and its associated rocks are of various ages, and are sedimentary deposits altered by exposure to a very high temperature.

14. Transition strata.—2d. *The Transition Strata.* These are super-imposed on the primitive, are more or less distinctly stratified, and contain the fossilized remains of animals and plants. They received the name of *transition*, because it was assumed that they had been formed at a period when the surface of the earth and the seas were passing into a state fit for the reception of organized beings. Modern researches have, however, shown that they are, like the primary rocks, strata modified by the effects of heat under great pressure.

15. Secondary strata.—3d. *The Secondary.* These have clearly originated from the destruction of the more ancient rocks, and have been deposited in hollows or depressions, by the action of rivers and seas. They abound in the mineralized remains of animals and plants; the most ancient inclosing

zoophytes and shells; the next in antiquity containing, in addition, vegetable remains and fishes; those which succeed enveloping not only fishes, shells, zoophytes, and plants, but also insects and bones of enormous reptiles, of birds, and of one or more genera of marsupial animals. The chalk is the uppermost, or most recent of this class. As the secondary rocks have manifestly been formed by the agency of water, it is clear that they were originally deposited in horizontal, or nearly horizontal layers or strata, although by far the greater portion has since been broken up, and now lies in directions more or less inclined to the horizon.

For the convenience of study, this subdivision of the rocks is still retained, as will hereafter be shown. To the above groups modern geologists have added a fourth class, the *Tertiary*.

16. Tertiary strata.—4th. *The Tertiary*.* These lie in hollows or basins of the chalk, and other secondary rocks, and are formed of the detritus of the more ancient beds. They abound in shells, plants, zoophytes, crustacea, fishes, &c.: and in them, with but one exception, the bones of mammalia first appear.

17. Alluvial deposits.—Of a later formation than the tertiary strata, are those accumulations of water-worn materials, which are spread over the surface of almost every country more or less abun-

* See Plate X. Fig. 3.

dantly. These are termed alluvial deposits;* they contain remains of the existing races of animals and plants, associated with those of species that are no longer to be met with on the face of the earth.

Even this slight examination of the strata affords convincing proofs of a former condition of animated nature, widely different from the present. We have evidence of a succession of periods of unknown duration, in which both the land and the sea teemed with forms of existence that have successively disappeared and given place to others; and these again to new races, approaching gradually more and more nearly to those which now inhabit the earth, till at length existing species make their appearance.

18. Geological mutations.—From this view of the physical structure of our planet we learn, at least so far as the limited powers of man can penetrate into the history of the past, that the distribution of land and water on its surface has been undergoing perpetual mutation; yet, that through a vast period of time, the physical condition of the earth has not materially differed from the present; that the dry land has been clothed with vegetation, and tenanted by appropriate inhabitants; and that the sea and the bodies of fresh water have swarmed with living forms; that at a remote epoch, though animal and vegetable life existed, the species were

* The term *diluvial* is applied by some geologists to the most ancient of these deposits; and that of *alluvial* to the modern accumulations only.

wholly different from any that now abound, and the greater number of a nature fitted to live in a temperature much higher, and more equally distributed, than occurs in the present state of the earth; and lastly, that in the inferior, or most ancient beds, all traces of mechanical action, and of animal and vegetable organization, are absent; or in other words, have either never existed, or *have been altogether obliterated.* Before entering upon that department of the subject to which the term Geology is commonly restricted, it will facilitate our comprehension of many of the appearances which the strata present to our notice, if in this place we endeavour to penetrate the mystery that veils the earliest condition of the earth; but this we shall in vain attempt, if we restrict our examination to the physical phenomena observable in our own planet.

19. Connexion of geology with astronomy.—Here Geology leads to Astronomy, and teaches us to look to the kindred spheres around us for the elucidation of the early history of the globe; and to consider the earth but as an attendant satellite on a vast central luminary. The solar system consists of the sun, whose mass is made up of solid matter, which is surrounded by a luminous atmosphere, or nebulosity; and of eleven small planets, which revolve around it in various periods; the earth being the third in distance from the sun, and in bulk, as compared with that body, of the size of

a pea to that of a globe two feet in diameter: and having a satellite, the moon, revolving round it.

TAB. 3.—TELESCOPIC VIEW OF THE MOON.

Upon examining the moon with powerful telescopes, we perceive that its surface is diversified by hills and valleys; that it is a congeries of mountains, many of which are manifestly volcanic, the lava currents being distinctly visible. We see in fact a torn, crateriform, and disturbed surface, like that which we may conceive would be presented by our earth, were the pinnacles of the granite mountains unabraded, and the valleys neither smoothed, nor filled up by sedimentary deposits.* In Venus

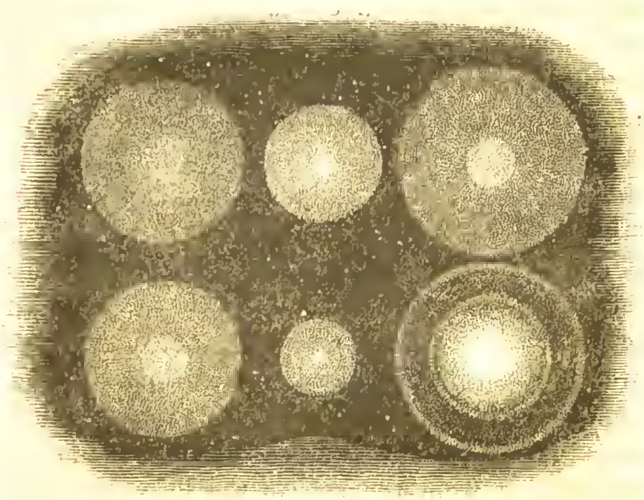
* See Appendix A.

and Mercury the mountains appear to be enormous; while in Jupiter and Saturn there are but slight traces of any considerable elevations.

20. Nebular theory of the universe.—Astronomy instructs us that in the original condition of the solar system the sun was the nucleus of a nebulosity, or luminous mass, which revolved on its axis, and extended far beyond the orbits of all the planets; the planets as yet having no existence. Its temperature gradually diminished, and becoming contracted by cooling, the rotation increased in rapidity, and zones of nebulosity were successively thrown off, in consequence of the centrifugal force overpowering the central attraction: the condensation of these separated masses constituted the planets and satellites. But this view of the conversion of gaseous matter into planetary bodies is not limited to our own system; it extends to the formation of the innumerable suns and worlds which are distributed throughout the universe. The sublime discoveries of modern astronomers have shown that every part of the realms of space abounds in large expansions of attenuated matter, termed *nebulæ,* which are irregularly reflective of light, of various figures, and in different states of condensation, from that of a diffused luminous mass, to suns and planets like our own. It must be admitted that this assertion appears astounding,—and that it may fairly be asked if man, the ephemeron of the material world, can measure the vast epochs which

mark the progressive development of suns and systems? The genius of Herschel has effected this wonderful achievement, and explained the successive changes by which suns and worlds are formed, through the agency of the eternal and unerring laws of the Almighty. By laborious and unremitting observations, that illustrious philosopher, and his highly gifted son, have demonstrated the progress of nebular condensation,—not indeed from the appearances presented by a single nebula, (for the process, probably, can only become sensible through the lapse of hundreds, or thousands, of years,) but by observations on the almost endless series of related, contemporaneous objects in every varied state of progression, from that of a cloud of luminous vapour, to the most dense and mighty orbs that appear in the firmament. As the naturalist in the midst of a forest is unable by a glance to discover that the trees around him are in a state of progressive change; yet perceiving that there are plants in different stages of growth, from the acorn just bursting from the soil to the lofty oak that stands the monarch of the woods, can readily, from the succession of changes thus at once presented to his view, ascertain the progression of vegetable life, although extending over a period far beyond his own brief existence:—in like manner, the astronomer, by surveying the varied condition of the heavenly bodies around him, can, by careful induction, determine the nature of those changes, which, as regards a single nebula, the human mind might otherwise be unable to ascertain.* Thus Herschel has traced from nebular masses of absolute vagueness, to others which present form and structure, the effects of the mysterious law which governs the stupendous stellular phenomena that are constantly taking place.

21. Different states of nebulæ.—Some of



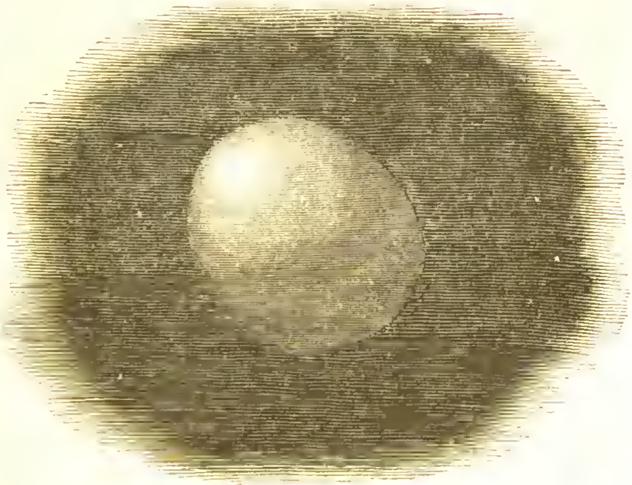
Tab. 4.—Telescopic appearance of various nebulæ.

the nebulæ appear as mere clouds of attenuated light—others as if curdling into separate masses—

* Sir John Herschel states, that the only change in a nebula which he has yet observed, is in that of Orion. A small transverse strip, which when he first figured that nebula was straight, had become *curved*, and showed a *knotty* appearance, which it did not before possess.—*Athenæum*, No. 565, p. 596.

while many seem assuming a spheroidal figure. Others again present a dense central nucleus of light surrounded by a luminous halo; and a series may thus be traced, from clusters of round bodies with one or more increased points of condensation, or of central illumination, to separate nebulæ with single nuclei, and with rings, to a central disk constituting a nebular star—and finally to an orb of light with a halo like the sun!

In the comets, those nebular bodies which belong to our own and other systems, we have evidence that even in the most diffused state of the luminous



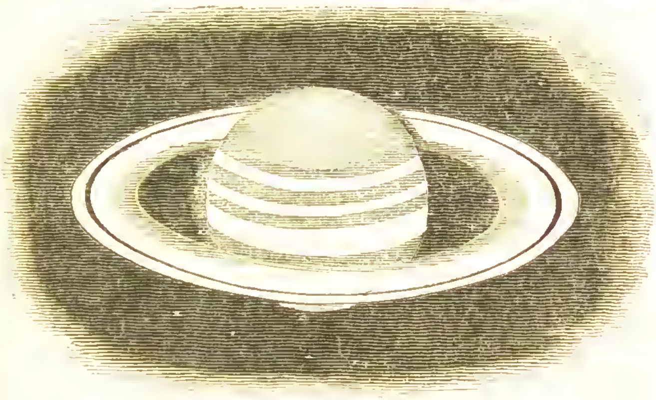
Tab. 5.—Telescopic view of Encke's comet.

matter, the masses which it forms are subservient to the laws of orbicular motion: of this fact an interesting proof is afforded by Eneke's eomet, that mere wisp of vapour, whieh in a period but little exeeeding three years, revolves around the eentral luminary of our system.

This beautiful theory of Hersehel, and La Plaee, explains by an easy and evident proeess the formation of planets and satellites, and aecounts for the uniform direetion of their revolutions. And not only is it believed that sueh is the law whieh the Creator has established for the maintenanee and government of the universe, but it is satisfaetorily shown, upon meehanieal prineiples, that sueh nebulæ *must of necessity produce* planetary bodies.

22. Formation of the solar system.—In our own system, the sun is a planetary orb with a luminous atmosphere, the eentral nueleus of a onee extensive nebulosity. During the eondensation of this nebula the planets were sueeessively thrown off; the most distant, as Hersehel, being the first or most aneient, followed by Saturn, Jupiter, the four asteroids, Mars, the Earth, Venus, and Mereury; the satellites, as distinet worlds, being the most reeent of the whole. It is inferred, that in any given state of the rotating solar mass, the outer portion or ring might have its eentrifugal foree exaetly balaneed by gravity; but inereased rotation would throw off that ring, whieh might sometimes retain its figure, of whieh we have a beautiful example in Saturn. This result, however,

could not take plaee unless the annular band were of uniform eomposition, whieh would rarely be the



Tab. 6.—Telescopic view of saturn.

ease; henee the ring would most generally divide into several portions, whieh might sometimes be of nearly equal bulk, as in the *asteroids;* while in others they might eoalesee into one mass. The solar nebulæ, thus separated at various periods, and eonstituting planets in a gaseous state, would neees-sarily have a rotatory motion, and revolve in varying orbits around the central nueleus; and as refrige-ration and consolidation proceeded, eaeh might projeet entire annuli or rings, and satellites, in like manner as the sun had thrown off the planets them-selves.

In addition to the appearanees presented by the nebulæ of various states of attenuation and of solidity, we have in the orbs of our own system evidenee of eorresponding gradations of density. The planets near to the sun are denser than those whieh are more distant: thus Mereury, whieh is the nearest, is the heaviest, being almost thriee as dense as the earth; while the density of Jupiter, whieh is far removed, is not more than one-third that of our planet; and Saturn, whieh, with the exception of Herschel, is the remotest, is but little more than one-eighth as dense; and is supposed to be as light as eork.*

But I must not pursue this sublime subjeet farther; those who feel desirous of more ample information may consult a popular abstraet of the diseoveries of modern astronomy, recently published, under the title of "Views of the Arehiteeture of the Heavens."†

You will at onee pereeive that this theory ean in no wise affeet the inferenee that the universe is the work of an all-wise and omnipotent Creator. "Let it be assumed that the point to which this hypothesis guides us, is the ultimate boundary of physieal seienee—that the nearest glimpse we ean attain of the material universe, displays it to us as oecupied by a boundless abyss of attenuated matter; still we are left to inquire how space became thus occupied —whenee originated matter thus luminous? And

* Introduction to Astronomy, by Sir J. F. W. Herschel.

† By Dr. Nichol, Professor of Practical Astronomy in the University of Glasgow.

if we are able to establish by physical proofs, that the first fact which the human mind can trace in the history of the heavens is, that '*there was light*, we are irresistibly led to the conclusion, that ere this could take place, 'God said, *Let there be light.*' "*

This theory of the condensation of nebular matter into suns and worlds, marvellous as it may appear, will be found on due reflection to offer the only rational explanation of the phenomena observable in the sidereal heavens, and in our own globe; and its beautiful simplicity is in correspondence with the unity of design so manifest throughout the works of the Eternal.

23. Gaseous state of the earth.—Though an unscientific inquirer may find it difficult to comprehend that our planet once existed in a gaseous state, this difficulty will vanish upon considering the nature of the changes that all the materials of which the earth is composed must constantly undergo. Water offers a familiar example of a substance existing on the surface of the globe, in the separate states of rock, fluid, and vapour; for water consolidated into ice is as much a rock as granite or the adamant, and, as we shall hereafter have occasion to remark, has the power of preserving for an indefinite period the animals and vegetables that may be therein imbedded. Yet, upon an increase of temperature, the glaciers of

* Professor Whewell.

the Alps, and the icy pinnacles of the Arctic circles, disappear; and, by a degree of heat still higher, would be resolved into vapour; and by other agencies might be separated into two invisible gases—oxygen and hydrogen. Metals may in like manner be converted into gases; and in the laboratory of the chemist, all kinds of matter easily pass through every grade of transmutation, from the most dense and compact to an aeriform state. We cannot, therefore, refuse our assent to the conclusion, that the entire mass of our globe might be resolved into a permanently gaseous form, merely by the dissolution of the existing combinations of matter.

24. Geology illustrated by astronomy.—From the light thus shed by modern Astronomy upon many of the dark and mysterious pages of the earth's physical history, we learn that the dynamical changes which have taken place in our globe—all the wonderful transmutations of its crust revealed to us by geological investigations—may be referable to the operation of the one, simple, and universal law, by which the condensation of nebular masses into worlds, through periods of time so immense as to be beyond the power of human comprehension, is governed.

The internal heat of the globe — the evidence afforded by fossil organic remains of a higher and more equally diffused temperature of the surface in an earlier state of the earth—and the elevations and dislocations of its crust which have taken place, and are still going on—all refer to such an origin, and to such a constitution of our planet, as that contemplated by the nebular theory. The elevatory process is not peculiar to the earth; for, as we have elsewhere remarked, Venus, Mercury, the Moon, and perhaps the Sun itself, exhibit evidence of a similar action.* In a philosophical point of view, the present physical epoch of the earth "is that of the fluidity of water, which is the nebulous bed or stratum last condensed, and which exerts mechanical and chemical action upon the previously consolidated materials." †

25. METEORITES.—Intimately connected with this division of our subject, is the remarkable fact of the fall of foreign bodies, called meteorites, or meteoric stones, on our earth. The specimen before me, for which I am indebted to my kind and distinguished friend, Professor Silliman, of Yale College, Newhaven, Connecticut, is a fragment of the mass which fell at Nanjenoy, in Maryland, in North America, a few years since. The following description by an eye-witness of its descent, will serve to illustrate the ordinary phenomena which attend the appearance of these mysterious visitors.‡

"On the 10th of February, between the hours of

* This subject is treated at large in Mr. De la Beche's "Researches in Theoretical Geology."

† Dr. Nichol.

‡ American Journal of Science.

twelve and one o'clock, I heard an explosion, as I supposed of a cannon, but somewhat sharper. I immediately advanced with a quick step about twenty paces, when my attention was arrested by a buzzing noise, as if something was rushing over my head, and in a few seconds I heard something fall. The time which elapsed from my first hearing the report to the falling, might have been fifteen seconds. I then went with some of my servants to ascertain where it had fallen, but did not at first sueeeed; however, in a short time the place was found by my cook, who dug down to the stone, which was discovered about two feet below the surface. It was sensibly warm, and had a sulphurous smell: was of an oblong shape, and weighed sixteen pounds and seven ounces. It has a hard vitreous surface. I have conversed with many persons, living over an extent of perhaps fifty miles square: some heard the explosion, while others noticed only the subsequent whizzing noise in the air; all agree in stating that the sound appeared directly over their heads. The day was perfeetly fine and clear. There was but one report heard, and but one stone fell, to my knowledge; there was no peeuliar smell in the air: it fell within 250 yards of my house."*

* An analysis of this meteorite gave the following results:—

| | |
|---|---|
| Oxide of Iron . . . . | 24. |
| ——— Niekel . . . | 1.25 |
| Silica with earthy matter | 3.46 |
| Sulphur, a trace. | — |
| | 28.71 |

26. Mrs. Somerville on meteorites.—That ornament and pride of her sex, Mrs. Somerville, has the following interesting remarks on this subject:—"So numerous are the objects which meet our view in the heavens, that we cannot imagine a part of space where some light would not strike the eye: innumerable stars—thousands of double and multiple systems—clusters in one blaze with their ten thousands of stars—and the nebulæ amazing us by the strangeness of their forms; till at last, from the imperfection of our senses, even these thin and airy phantoms vanish in the distance. If such remote bodies shone by reflected light, we should be unconscious of their existence; each star must then be a sun, and may be presumed to have its system of planets, satellites, and comets, like our own; and for aught we know, myriads of bodies may be wandering in space, unseen by us, of whose nature we can form no idea, and still less of the part they perform in the economy of the universe. Nor is this an unwarranted presumption: many such do come within the sphere of the earth's attraction, are ignited by the velocity with which they pass through the atmosphere, and are precipitated with great violence to the earth. The fall of meteoric stones is much more frequent than is generally believed: hardly a year passes without some instances occurring; and if it be considered that only a small part of the earth is inhabited, it may be presumed that numbers fall into the ocean, or on

the uninhabited parts of the land, unseen by man. They are sometimes of great magnitude: the volume of several has exceeded that of the planet Ceres, which is about seventy miles in diameter. One which passed within twenty-five miles of us was estimated to weigh about *six hundred thousand* tons, and to move with a velocity of about twenty miles in a second—a fragment of it alone reached the earth. The obliquity of the descent of meteorites, the peculiar substances of which they are composed, and the explosion attending their fall, show that they are foreign to our planet. Luminous spots, altogether independent of the phases, have been seen on the dark parts of the moon; these appear to be the light arising from the eruption of volcanoes; whence it has been supposed that meteorites have been projected from the moon by the impetus of volcanic eruption. If a stone were projected from the moon in a vertical line with an initial velocity of 10,992 feet in a second—a velocity but four times that of a ball when first discharged from a cannon—instead of falling back to the moon by the attraction of gravity, it would come within the sphere of the earth's attraction, and revolve around it like a satellite. These bodies, impelled either by the direction of the primitive impulse, or by the disturbing action of the sun, might ultimately penetrate the earth's atmosphere and arrive at its surface. But from whatever source meteoric stones may come, it is highly probable that they have a common origin, from the uniformity, we may almost say identity, of their chemical composition."*

27. Origin of meteorites.—Von Hoff, in an admirable essay on the origin of meteoric stones,† observes, that although it is demonstrated mathematically, that aerolites and masses of native iron which fall from the air, *may* be derived from the moon, yet the weight of evidence is in favour of their being nebulous matter suddenly condensed, and descending to this planet's surface when this mysterious process takes place within the sphere of the earth's attraction. These masses present a general correspondence in their structure and appearance, having (with the exception of native iron) a crystalline character internally, and externally a black slaggy crust, as in this specimen from Nanjenoy.

Assuming then that our planet, when first called into being by the fiat of the Creator, was a gaseous mass "without form and void," and destined through indefinite ages to undergo mutations which were designed ultimately to prepare it for the abode of the human race, we proceed to investigate the causes and effects of those agencies by which its surface is still modified. The consideration of what Sir John Herschel so emphatically terms "that mystery of mysteries," the successive appearance of

* Connexion of the Physical Sciences, p. 423. 4th Edition.

† A Translation of this Memoir appeared in Jameson's Edinburgh New Philosophical Journal, July 1837.

new forms of organic life on our globe, will be reserved for the concluding lecture.

28. Existing geological changes.—In this division of the subject, it will be my object to explain in a clear and familiar manner some of those physical changes which, unheeded or unappreciated, are taking place around us; but which operating on a large scale, and through a long period of time, are capable of producing effects that materially modify the earth's surface, and give rise to results which, when viewed in the aggregate, fill the uninformed mind with astonishment, and cause it to call up imaginary convulsions and catastrophes to explain the result of some of the most simple operations of nature. As the mere lines that compose the alphabet constitute, when placed in combination, the mighty engine by which the master spirits of our race enlighten and benefit mankind; so natural processes, in themselves apparently inadequate to produce any important effects, become, by their combined and continued operation, an irresistible power, by which the dry land is converted into the bed of the ocean, and the bed of the ocean into dry land; thus fulfilling that universal law of the Creator, which subjects every particle of matter to incessant change.

Before proceeding farther in this inquiry, I would notice an opinion, so generally prevalent that it may possibly be entertained by some present, namely, that the phenomena which will come under our consideration, have been produced by the deluge recorded in Scripture. But whatever may have been the modifications of the earth's surface produced by that catastrophe, they must on the present occasion be wholly excluded from our consideration, for the changes to which geological inquiries relate are of a totally different character, and referable to periods long antecedent to that miraculous event.

I have now to direct your attention to those natural operations which, when properly investigated, will afford an easy explanation of facts of the highest interest and importance; will teach us how this limestone has been formed of brittle shells, and this marble filled with the coral to which it owes its beautiful markings—how wood has been changed into stone, and plants and fishes have become inclosed in the solid rock. I wish to explain to you that the ground on which we stand was not always dry land, but once constituted the bed of the sea—that the hills, now so smooth and rounded, and clothed with beautiful verdure, have been formed in the profound depths of the ocean, and may be regarded as vast tumuli, in which the remains of beings that lived and died in the early ages of the globe are entombed;—and that the weald of Kent and Sussex, that rich and cultivated district which fills up the area between the chalk hills of Sussex, Surrey, Kent, and Hampshire, was once the delta of a river, that flowed through a country which is now swept from the face of the earth—a country more marvellous than any that even romance or poetry has ventured to portray.

29. EFFECTS OF STREAMS AND RIVERS. — In pursuance of this object I shall first take into consideration the action of running water—of streams, and rivers. I need not dwell on those meteorological causes by which the descent of moisture on the surface of the earth is regulated; but shall content myself with observing, that rivers are the great natural outlets which convey the superfluous moisture of the land into the grand reservoir, the ocean. And so exactly is the balance of expenditure and supply maintained, that all the rivers on the face of the earth, though constantly pouring their mighty floods into the ocean, do not affect its level in the slightest perceptible degree; we may therefore assume that the quantity of moisture evaporated from the surface of the sea, is exactly equal to the sum of all the water, in all the rivers in the world. But although the body of fresh-water poured by the rivers into the basin of the ocean is again displaced by evaporation, yet there is an operation silently and constantly going on, which becomes an agent of perpetual change. The rivulets which issue from the mountains are more or less charged with earthy particles, worn from the rocks and strata over which they flow: their united streams in their progress towards the rivers become more and more loaded with adventitious matter; and as the power of

abrasion becomes greater, by the increase in the quantity and density of the mass of water, a large proportion of materials is mechanically or chemically suspended in the fluid, and carried into the sea. If the current be feeble, much of the mud, and the larger pebbles, will be thrown down in the bed of the river—hence the formation of the alluvial plains in the valleys of the Arun, the Adur, the Ouse, and Cuckmere, in this county.* But the greater portion will be transported to the mouths of the rivers, and there form those accumulations of the fluviatile spoils of the land which constitute deltas; the finest particles, however, will be carried far into the sea, and, transported by currents and agitated by the waves, will at length be precipitated into the profound and tranquil depths of the ocean. But the waters convey not only the mud and water-worn materials of the country over which they flow: leaves, branches of trees, and other vegetable matter—and the remains of the animals that fall into the streams, with shells and other exuviæ, human remains, and works of art, are also constantly transported and imbedded in the mud, silt, and sand of the delta, some of these remains being occasionally drifted out to sea, and deposited in its bed.

30. Deltas of the Ganges, and Mississippi. —The changes here contemplated, as they are going

* Sussex.

on in our own island, may appear insignificant, and incapable of producing any material effect on the earth's surface; but if we trace the results in countries where these agents are now operating on a larger scale, we shall at once perceive their importance, and that time only is wanting, to form accumulations of strata, equal in extent, and of the same character with many of those ancient deposits, which will hereafter come under our observation.

From experiments made with great care, it has been ascertained that the quantity of solid matter brought down by the Ganges and carried into the sea annually, is equal to 6,368,077,440 tons: in other words, to a mass of solid materials, equal in size and weight to sixty times that of the great pyramid of Egypt; the base of that stupendous structure covering eleven acres, and its perpendicular height being 500 feet.* The Burrampooter, another river in India, conveys annually as much earthy matter into the sea as the Ganges. The waters of the Indus, as the celebrated traveller, Captain Burns, informed me, are alike loaded with earthy materials.

In the mighty rivers of America, the same effects are observable; the quantities of trees brought down by the Mississippi and imbedded in its deposits are almost incredible, and the basin of the sea around the embouchure of that river, is becoming shallower

* Lyell's Principles of Geology.

every day, by the sole agency of the operations now under consideration. In the sediments of these rivers, the animals as well as the plants of the respective countries are continually enveloped. It is therefore evident, that should these deltas become dry land, the naturalist could, by an examination of the animal and vegetable remains imbedded in the fluviatile sediments, readily determine the characters of the fauna and flora of the countries through which the rivers had flowed. We may here observe, that in tropical regions, where animal life is profusely developed, and but little under the control of man, the animal remains buried in deltas, are far more abundant than in those of European countries, which are thickly peopled, and in a high state of civilization. The enterprising, but unfortunate Lander informed me, just before he embarked on his last fatal expedition to Africa, that many parts of the Quorra, or Niger, so far as the eye could reach, teemed with crocodiles and hippopotami; and so great was their number, that he was oftentimes obliged to drag his boat on shore lest it should be swamped by these animals. But it is unnecessary for me to dwell longer on these operations; it will suffice to have shown, that by the simple effect of running water, great destruction and modification of the surface of the land are everywhere taking place; and at the same time, fluviatile deposits are forming on an extensive scale, and enveloping animal and vegetable remains. Thus, in the deltas of the rivers of this country, we find the bones and antlers of the deer, horse, and other domesticated animals, with the trunks and branches of trees and plants of our island, river and land shells, human bones, fragments of pottery and other works of art: while in those of the Ganges and the Nile, the remains of the animals and vegetables of India and of Egypt are respectively entombed.

31. Formation of strata. — There is one circumstance connected with these facts which it will be necessary here to consider. The quantity of water in streams and rivers varies considerably at different periods of the year; in the rainy season the rivers are overflowing, and the waters remarkably turbid: the depositions, therefore, must be much greater at those periods than in the summer months, when the streams are feeble, and the rivers shallow. In that part of the river affected by the tides, there is also a constant flux and reflux of the waters, and from these causes the depositions must, to a certain degree, be periodical. Accordingly we find them disposed in *strata* or layers, from the partial consolidation of the surface of one bed of mud, before the superincumbent layer was precipitated upon it. Thus wherever a fresh break takes place in a bank of consolidated mud, in the delta of the Nile, it is easy to trace the deposits of each successive year, by means of the lighter earth on the top of each. When a portion is taken into the hand, it separates into layers; and on closely

examining the edges of these, very delicate thin lines are perceptible, showing a laminated structure, like those observable in the coal-shales. Judging from these layers, the annual deposits appear to vary considerably, but the average thickness is little more than a quarter of an inch.*

Where a river terminates in an extensive estuary, the sea throws over the layer of mud brought down by the river, a covering of sand: and frequently these alternate with the greatest regularity, the receding of the tide allowing the fresh water to deposit its mud, and the advance of the sea discharging sand and marine exuviæ over the surface.

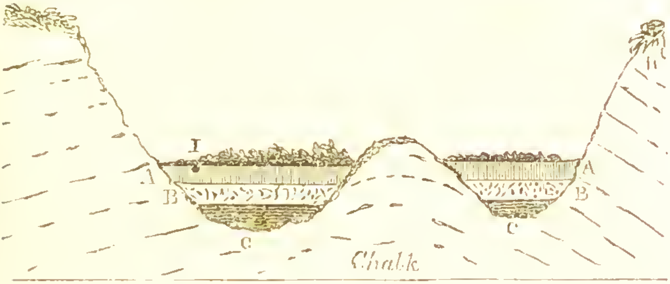
32. Rippled sand.—And here we may notice another phenomenon. Every one must have observed, when walking by the banks of a river at low water, or on the sands of the sea-shore, that when the water has been agitated by the wind, the surface of the mud, or sand, is undulated, or furrowed over by the rippling of the waves, the marks presenting various appearances, according to the force and direction of the currents. Frequently too, the vermes and molluscous animals mark the surface with meandering lines, and ridges; and these varied markings on the sand are preserved, if a thin layer of mud happen to be deposited over them before the next advance of the waves. I shall have

* Letter to Professor Silliman from an American who visited Egypt in 1834.

occasion to refer to these appearances hereafter. We must also remark that there are certain kinds of mollusca, or shell-fish, that can only live in fresh water; others that are confined to the sea; while a third class is restricted to the brackish waters of estuaries. Accordingly, in the deposits under consideration, the river and estuary species are abundant, while the marine only occur as stragglers, and are comparatively rare. Land plants, and those which affect a marshy soil, as the equiseta, or mare's-tails, reeds, rushes, &c. are likewise often accumulated in such quantities as to form beds of peat.

33. LEWES LEVELS.—It will serve to impress the subject more forcibly upon our minds, if we refer to some local example of fluviatile deposits: and from its immediate vicinity to Brighton, I select the valley of the Ouse, between Newhaven and Lewes, which is one of several estuaries from whence the sea has retired within the last eight or ten centuries. This valley is bounded by an amphitheatre of chalk hills, into which the river enters through a gorge of the Downs on the north, and pursuing a tortuous course, discharges its waters at Newhaven. This alluvial plain is called Lewes Levels, and is here and there flanked by headlands, and ancient cliffs; while a few insular mounds of chalk rise up through the fluviatile depositions, which have been accumulating during a long period of time. The following diagram represents a section of the valley of the Ouse, from east to west.

Here we have a depression (or *basin*, as it is termed by geologists) of the chalk, partially filled




TAB. 7.—VERTICAL SECTION OF LEWES LEVELS.*

up by layers of indurated mud or silt, the surface of which is clothed with verdure; the bed of the river (I.) is situated near the eastern chalk cliffs. The deposits which repose on the chalk are as follow :—

1. A bed of peat about five feet in thickness: formed of decayed twigs and leaves of the hazel, oak, birch, &c. inclosing trunks of large trees.

2. (A. A.)—Blue clay, or indurated mud, containing several species of fresh-water shells, like those which now inhabit the river and ditches; with numerous *indusiæ*, or cases of the larvæ

* A *geological section* represents the internal structure of the earth on any given line, in a vertical direction; and is either (1) *natural*, as seen in cliffs, precipices, &c.; (2) *artificial*, as in quarries, tunnels, and other excavations; or (3) *ideal*, when constructed from combinations of observations on the position of strata in various localities.

of *phryganeæ*, or caddis-worms. Bones of the horse, and deer, also occur in the lower part of this bed.

3. (B. B.)—Clay, containing fresh-water shells, with an intermixture of existing marine species, as the common cockle, (*cardium edule*,) tellina, &c.

4. (C. C.)—Blue clay, inclosing marine shells, viz. cockles, muscles, &c. without any intermixture of fluviatile species. In this bed a skull of the narwal, or sea-unicorn (*Monodon monoceros*,) and of the porpoise have been discovered.

From the nature of these deposits we learn that this valley was once an arm of the sea, and that the sequence of the physical changes which took place was as follows:—

*First*, There was a salt-water estuary, inhabited by marine shell-fish of the same species as those now existing in the British Channel; and into which cetacea occasionally entered.

*Secondly*, The inlet grew shallow, the water brackish, and marine and fresh-water shells were mingled in its blue argillaceous sediment.

*Thirdly*, The shoaling continued until fresh-water so much predominated, that fluviatile shells, and aquatic insects, could alone exist.

*Fourthly*, A peaty swamp, or morass was formed, by the drifting of trees, and plants, from the forest of Andreadswald, which formerly occupied the weald of Sussex; and terrestrial quadrupeds were occasionally imbedded.

*Lastly*, The soil being inundated by land floods at distant intervals only, became a verdant marshy plain.*

34. Remains of man in modern alluvium.—But the sediments in the river valleys of the South Downs often contain not only the bones of the deer, horse, boar, and other terrestrial animals, but also human skeletons, which are sometimes found inclosed in coffins of exceedingly rude workmanship: together with canoes,† and other relics

* Geology of the South-east of England, p. 16.

† *Ancient British Canoe.* In 1835 a canoe was discovered at the depth of several feet in a bed of silt, occupying an ancient branch of the river Arun, at North Stoke, near Arundel. It was presented, by my noble friend the late Earl of Egremont, to the British Museum; and is placed on the right hand of the entrance of the court. This canoe is nearly thirty-five feet in length, four and a half wide in the centre, three feet three inches broad at one extremity, and two feet ten inches at the other; and is about two feet deep. It is formed of the single trunk of an oak, which has been hollowed out and brought to its present shape with great labour; it is evidently the workmanship of a very remote period, and in all probability was constructed by some of the earliest inhabitants of our island, before the use of iron or even brass was known: the original tree must have been fifteen or sixteen feet in circumference. Three projections, left in the interior of the boat, appear to have been designed for seats; it is manifest therefore that the persons who constructed this vessel were unacquainted with the art of forming boards. This canoe is so similar to some of those which were fabricated by the aborigines of North America, when first visited by Europeans, that we can have no hesitation in concluding that it was constructed in a similar manner; namely, by charring such portions of the tree as were to be removed, and scooping them out with

of the early inhabitants of our island. This human skull, for which I am indebted to Warren Lee, Esq. of Lewes, was dug up at a great depth in the blue silt of Beeding Levels; it was inclosed, together with the other bones of the skeleton, in a coffin of oak, which was evidently of high antiquity, being formed of four rude planks, or rather squared trunks of trees, held together by oaken pegs. The skull is of a dark bluish-brown colour, like the bones of the deer and horse of similar deposits; an appearance attributable to an impregnation of iron; when first dug up, blue phosphate of iron filled up the interstices of the bones. The state of the teeth is remarkable; they are worn down almost smooth, although the individual must have been in the prime of life; a fact which seems to indicate that grain, or some other hard substance, constituted a large proportion of his customary food.

35. Peat bogs.—Before proceeding to the next subject, I will advert to those extensive accumulations of vegetable matter called Peat Bogs. These are morasses, covered with successive layers or beds of mosses, reeds, equiseta, rushes, and other plants that affect a marshy soil; and in particular of a kind of moss, the *sphagnum palustre*, which frequently constitutes a large proportion of the entire mass.

stone instruments: no doubt this canoe belongs to the same period as the flint and stone instruments called *celts*, which are found in the tumuli on the South Downs; it is now in the state of peat or bog-wood.

The beds of peat are annually augmented by the peculiar mode of increase of the peat-moss, which throws up a succession of shoots to the surface, while the parent plants decay, and form a new layer of the soil.

The peat bogs of Ireland are of great extent: one of the mosses on the banks of the Shannon is two or three miles in breadth, and fifty in length. Mr. Lyell remarks, that the peat-mosses of the North of Europe occupy the areas of the ancient forests of oak and pine; and that the fall of trees from the effect of storms, or natural decay, by obstructing the draining of a district, and thus giving rise to a marsh, is the origin of most of the peat bogs; mosses, and other marsh plants, spring up, and soon overwhelm and bury the prostrate forests; hence the occurrence of trunks and branches of enormous oaks, firs, &c. with their fruits.

De Luc states, that the sites of many of the aboriginal forests on the continent are now covered by mosses and fens, and that many of these changes are attributable to the destruction of the forests by the Romans. A remarkable fact relating to peat bogs must not be omitted; namely, the occasional occurrence of the bodies of men and animals, in a high state of preservation, at a great depth. In some instances the bodies are converted into a fatty substance, resembling spermaceti, called *adipocire*.

36. Conversion of peat into coal.*—A

* Dr. Jackson on the Geology of Maine.

fact of great geological interest is the occurrence of coal in peat bogs, since it proves that the conversion of vegetable matter into a mineral, the origin of which was formerly deemed questionable, takes place, wherever circumstances are favourable for the production of the bituminous fermentation. In Limerick, in the district of Maine, one of the States of North America, there are peat bogs of considerable extent, in which a substance exactly similar to *cannel coal* is found at the depth of three or four feet from the surface, amidst the remains of rotten logs of wood, and beaver sticks: the peat is twenty feet thick, and rests upon white sand. This coal was discovered on digging a ditch to drain a portion of the bog, for the purpose of obtaining peat for manure. The substance is a true bituminous coal, containing more bitumen than is found in any other variety.* Polished sections of the compact masses exhibit the peculiar structure of coniferous trees, and prove that the coal was derived from a species allied to the American fir. It has probably been formed by the chemical changes supervening upon fir-balsam, during its long immersion in the

* An analysis of 100 grains gave the following results:

| | |
|---|---|
| Bitumen . . . . . | 72 |
| Carbon . . . . . . . | 21 |
| Oxide of iron . . . . | 4 |
| Silica . . . . . . . | 1 |
| Oxide of Manganese . | 2 |
| | 100 |

humid peat; the circumstances under which it was placed being most favourable for that process to take place, by which, as we shall show hereafter (see Lecture VI.), vegetable matter is converted into coal.

37. SUBTERRANEAN FORESTS.—Independently of the trees immersed in peat bogs and morasses, there are also found entire forests buried deeply in the soil; the trees having their roots, trunks, branches, fruits, and even leaves, more or less perfectly preserved. Several accumulations of this kind have been discovered on the coast of Sussex, occupying low alluvial plains, that are still subject to periodical inundations.* The trees are chiefly of the oak, hazel, fir, birch, yew, willow, and ash; in short, almost every kind that is indigenous to this island occasionally occurs. The trunks, branches, &c. are dyed throughout of a deep ebony colour by iron; and the wood is firm and heavy, and sometimes sufficiently sound for domestic use. In Yorkshire it is employed in the construction of houses. The specimens which I now place before you, for which I am indebted to Professor Babbage, exhibit the usual characters of such remains; they are portions of large trunks of yew, oak, and fir, from a peat bog in Ireland.

38. GEOLOGICAL EFFECTS OF THE SEA.—While the mountains, valleys, and plains of the interior of a country, are undergoing slow but perpetual change by the combined effects of atmospheric

* See Illustrations of the Geology of Sussex, p. 288.

agency, and of running water, the coasts, and shores, are exposed to destruction from the action of the waves, and the encroachments of the sea. When the land presents a high and rocky coast, the waves, by their incessant action, undermine the cliffs, which at length fall down, and cover the shore with their ruins. The softer parts of the strata, as the chalk, marl, clay, &c. are rapidly disintegrated and washed away; while the more solid materials are broken, and rounded, by the continual agitation of the water, and give rise to those accumulations of beach and sand which skirt our sea-cliffs, and serve, in some situations, to protect the land from further encroachments. But when the cliffs are entirely composed of soft substances, their destruction is very rapid, unless artificial means be employed for their protection; which, however, in many instances are wholly ineffectual.

The encroachments of the ocean upon the land effected by this operation, often give rise to sudden and extensive inundations, and the destruction of whole tracts of country. Along the Sussex coast the inroads of the sea have been noticed in the earliest historical records; and the site of the ancient town of Brighton has been entirely swept away, the sands, and the waves, now occupying the spot where the first settlers on these shores fixed their habitations.* On low and sandy coasts, the waves drive the loose and lighter materials towards the land; and the

* See Geology of the South-East of England, p. 23.

drifted sand, becoming dry at the reflux of the tide, is carried by the wind inland, and in some situations is accumulated in such quantities as to form ranges of hills, which in their progress overwhelm fertile tracts, and engulf churches, and even entire villages. These sand banks or downs, loose and fluctuating as they are in their first stage of advancement, become, under certain circumstances, fixed, and converted into solid stone—a process to which we shall presently advert.

39. Bed of the ocean.—But the production of beach, gravel, and sand, on the shores, and the drifting of sand inland, are effects far less important than those which are going on in the profound depths of the ocean. In the tranquil bed of the sea, the finer materials, held in mechanical or chemical suspension by the waters, are precipitated and deposited, enveloping and embedding their inhabitants, together with the remains of such animals and vegetables of the land as may be floated down by the streams and rivers. But, in the beautiful language of Mrs. Hemans,—

"The depths have more! What wealth untold
  Far down and shining through their stillness lies!
They have the starry gems, the burning gold,
  Won from a thousand royal argosies!

"Yet more—the depths have more! Their waves have roll'd
  Above the cities of a world gone by—
Sand hath filled up the palaces of old,
  Sea-weed o'ergrown the halls of revelry.

"To them the love of woman hath gone down,—
Dark flow their tides o'er manhood's noble head,
O'er youth's bright locks, and beauty's flowery crown."—

Yes! in these modern depositions, the remains of man, and of his works, must of necessity be continually engulfed, together with those of the animals which are his contemporaries.

Of the nature of the bed of the ocean, we can of course know but little from actual observation. Soundings, however, have thrown light upon the deposits now forming in those depths, which are accessible to this mode of investigation; and thus we learn, that in many parts immense accumulations of the remains of testaceous animals, intermixed with sand, gravel, and mud, are going on. Donati ascertained the existence of a compact bed of shells, 100 feet in thickness, at the bottom of the Adriatic, which in some parts was converted into marble. In the British Channel, extensive banks of sand, imbedding the remains of shells, crustacea, &c. are in the progress of formation. This specimen, which was dredged up a few miles from land, off Brighton, is an aggregation of sand with recent marine shells, oysters, muscles, limpets, cockles, &c. and minute corallines; and this example, from off the Isle of Sheppey, consists entirely of cockles (*Cardium edule*), held together by conglomerated sand. In bays and creeks, bounded by granitic rocks, the bottom is found to be composed of micaceous and quartzose sand, consolidated into what may be termed regenerated granite. Off Cape Frio, on the Brazilian coast, solid masses of this kind were formed in a few months, and in them were found imbedded, dollars and other treasures from the wreck of a vessel, to recover which an exploration by the diving bell was undertaken.

40. Currents, and their effects.—The distribution over the bottom of the sea of the detritus brought down by rivers and streams, and of the materials worn away by the action of the waves on the shores, is principally effected by the influence of currents, which, from their regularity, permanency, and extent, may be considered as the rivers of the ocean. To this agency I can but briefly allude, and shall restrict my remarks to the Gulf-stream, which is the great current that transports the waters, and the temperature of the tropical regions, into the climates of the north. From the mouth of the Red Sea a current about 50 leagues in breadth sets continually towards the south west; doubling the Cape of Good Hope, it assumes a north-west direction, and in the parallel of St. Helena, its breadth exceeds 1000 miles; then taking a direction nearly east, it meets in the parallel of 3° north, along the northern coast of Africa, with a current from the north; entering the Gulf of Florida, they are reflected and form the Gulf-stream, which, passing along the coast of North America, stretches across the Atlantic to the British Isles. At the parallel of 38°, nearly 1000 miles from the Straits of Bahama,

the water of the stream is ten degrees warmer than the air. The course of the Gulf-stream is so fixed and regular, that nuts and plants from the West Indies are annually drifted to the western islands of Scotland. The mast of a man-of-war, burnt at Jamaica, was driven ashore several months afterwards on the Hebrides, "after performing a voyage of more than 4000 miles under the direction of a current which, in the midst of the ocean, maintains its course as steadily as a river upon the land."* The quantity of detritus transported by such a current must be immense, and we therefore need not wonder at frequently finding the productions of different climates associated together in a fossil state.

41. Incrusting springs, &c.—The phenomena hitherto considered, are referable to the mechanical action of water; and the effect has been that of disintegration, and destruction, in the first instance; and in the second, of accumulations of sediments in water-channels, and in the bed of the sea. We must now refer to an operation of a totally different character—the power possessed by streams, as clear and sparkling as poet ever feigned, or sung, of consolidating loose materials, of converting porous strata into solid stone, and of filling up their own channels by the deposition of calcareous matter.

That most fresh water holds a certain proportion

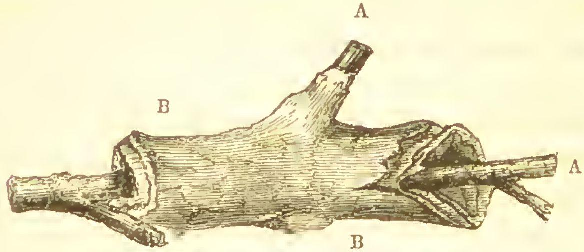
* Playfair's Works, edition 1822; vol. i. p. 414.

of carbonate of lime* in solution, is well known; and also that changes of temperature, as well as many other causes, will occasion the calcareous earth to be in part or wholly precipitated. The *fur*, as it is called, that lines a boiler which has been long in use, affords a familiar illustration of this fact. At the temperature of 60°, lime is soluble in 700 times its weight of water; and if to the solution a small portion of carbonic acid be added, a carbonate of lime is formed, and precipitated in an insoluble state. If, however, the carbonic acid be in such quantity as to supersaturate the lime, it is again rendered soluble in water; and it is thus that carbonate of lime, held in solution by an excess of fixed air, not in actual combination with the lime, but contained in the water and acting as a menstruum, is commonly found in all waters. An absorption of carbonic acid, or a loss of that portion which exists in excess, will therefore occasion the calcareous earth to be set free, and precipitated on any substances in the water, such as stones, sprigs, and leaves of trees, &c. Some springs contain so large a proportion of calcareous earth when they first issue from the rocks, and so speedily throw it down in their course, that advantage has been taken of the circumstance to obtain incrustations of various

* *Carbonate of lime* consists of lime in combination with carbonic acid gas, which is a most abundant natural product. This gas is unrespirable, and when pure, will immediately suffocate an animal immersed in it. It extinguishes flame.

objects, as leaves, branches, baskets, nests with eggs, and even old wigs. The incrusting springs of Derbyshire are celebrated for such productions. These depositions are termed tufa, or travertine; and in Italy, and many other countries, they constitute extensive beds of concretionary limestone, which is often of a crystalline structure. The Cyclopean walls and temples of Pæstum, are formed of this substance. At the baths of San Filippo, in Tuscany, where the waters are highly charged with tufa, this property is applied to a very ingenious purpose. The stream is directed against moulds of medallions, and other bas-reliefs, and very beautiful casts are thus obtained; of which we have an example in this medallion, which bears the head of Napoleon, and was presented to me by the Marquis of Northampton.

42. Incrustations not petrifactions.—As specimens of this kind are commonly, but errone-




Tab. 8.—Incrustation.

A A A, *Extremities of the twig unchanged;* B B, *the tufaceous crust.*

ously, termed petrifactions, I will briefly explain their real nature. We have before us several incrustations from various places: baskets of shells, and nests with eggs, from Derbyshire; a bird, from Knaresborough, in Yorkshire; and a twig, partially incrusted, from Ireland.

I need scarcely observe, that on breaking such specimens, we find the inclosed substances to have undergone no change but that of decay, in a greater or less degree. In this incrusted bird's nest, the twigs of which it is composed, like the branch above mentioned, are exposed in several places, and, as you perceive, are not permeated by stony matter, but are dry, and brittle. Now, a true *petrifaction* is altogether of a different nature, the substance being saturated throughout with mineral matter; if we break it, we find that every part of its structure has undergone a change; sometimes flint has filled up the interstices, and upon slicing and polishing it, the most delicate texture of the original may be detected. Wood, for instance, which is so commonly petrified by flint or chalcedony, may be cut so thin, that with a powerful lens the ramifications of the vessels and the structure of the tissues may be seen, and from their form, and disposition, we may determine the particular kind of tree to which the specimen belonged, although it may have been cased up in stone for ages. When bone is petrified, the same phenomena are observable; the most delicate parts of the internal structure are preserved, and all the cells are filled up with stone or spar, which is oftentimes of a different colour from that of the walls of the cells, and thus a natural anatomical preparation, of great beauty and interest is formed.

43. Lake of the Solfatara.—The celebrated lake of the Solfatara lies in the Campagna between Rome and Tivoli, and is fed by a stream of thermal water which flows into it from a neighbouring pool. The water is of a high temperature, and is saturated with carbonic acid gas, which, as the water cools, is constantly escaping, and keeping up an ebullition on the surface. The formation of travertine is so rapid, that not only the vegetables and shell-fish are surrounded and destroyed by the calcareous deposition, but insects also are frequently incrusted. In these beautiful specimens of travertine from Solfatara, vegetable impressions are distinctly seen, the cavities in the mass having been occasioned by the decomposition of the vegetable matter.* The stream that flows out of the lake fills a canal, which is conspicuous at a distance, from the line of vapour emanating from the water.

A considerable number of the edifices of both ancient and modern Rome, are constructed of travertine, derived from the quarries of Ponte Luccano, which have clearly originated from a lake of the same kind. Pæstum is also built of calcareous tufa, derived from similar deposits. "The waters of these lakes," says Sir Humphry Davy, "have their rise at the foot of the Apennines, and hold in solution carbonic acid, which has dissolved a portion of

* See Appendix B.

the calcareous rocks through which it has passed; the carbonic acid is dissipated by the atmosphere, and the marble, slowly precipitated, assumes a crystalline form, and produces coherent stones. The acid originates in the action of volcanic fires on the calcareous rocks of which the Apennines are composed, and carbonic acid being thus evolved, rises to the source of the springs derived from the action of the atmosphere, gives them their impregnation, and enables them to dissolve calcareous matter."

44. Marble of Tabreez.—In Persia, a beautiful transparent limestone, called Tabreez marble, is formed by deposition from a celebrated spring near Maragha, where the whole process of its formation may be seen. In one part the water is clear, in another dark, muddy, and stagnant; in a third it is very thick, and almost black; while in the last stage it is of a snowy whiteness. The petrifying pools look like frozen water: a stone thrown on them breaks the crust, and the water exudes through the opening; and in some states the process has proceeded so far as to admit of walking on the surface of the lake. A section of the stony mass resembles an accumulation of sheets of paper, being finely laminated; and such is the tendency of this water to solidify, that the very bubbles on its surface become hard, as if they had been suddenly arrested, and metamorphosed into stone.*

* Morier's Travels.

45. STALACTITES, AND STALAGMITES.—By the infiltration of water through limestone rocks, into fissures and cavities, sparry concretions are produced on the roofs, sides, and floors of caverns. The concretionary masses which are dependent from the roof like icicles, are called *stalactites;* those which form on the floor, from the droppings of the water, are termed *stalagmites;* and when, as frequently happens, the two unite, a singularly picturesque effect is produced,—the caves appearing as if supported by pillars of the most extraordinary beauty and variety.* Sometimes a linear fissure in the roof, by the direction it gives to the dropping of the lapidifying water, forms a transparent curtain or partition. A remarkable instance of this kind occurs in a cavern in North America, called Weyer's Cave, which is situated in the limestone range of the Blue Mountains.† There are also many caverns in England, celebrated for the variety and beauty of their sparry ornaments: those in Derbyshire are well known.

46. GROTTO OF ANTIPAROS.—The Grotto of Antiparos in the Grecian Archipelago, not far from Paros, is justly admired. The sides and roof of its principal cavity are covered with immense incrustations of calcareous matter, which form either stalactites, depending from above, or irregular pillars rising from the floor. Several perfect columns reaching to the ceiling have been formed, and others

* Appendix C. † Appendix D.

are still in the course of formation, by the union of the stalactite from above, with the stalagmite below. These being composed of matter slowly deposited, have assumed the most fantastic shapes; while the pure, white, and glittering spar, beautifully catches and reflects the light of the torches of the visitors to this subterranean palace, in a manner which causes all astonishment to cease at the romantic tales told of the place—of its caves of diamonds, and of its ruby walls; the simple truth, when deprived of all exaggeration, being sufficient to excite admiration, and awe. Some of these concretions form a thin curtain, which is perfectly transparent.

The specimens which I have selected from my collection, to illustrate these remarks, exhibit the usual character of stalactitical concretions; those long stony icicles are from Portland; and these minute straws of spar, from an archway near the Chain Pier, have been formed by the infiltration of rain through the superincumbent bed of calcareous rock. This mass of pebbles, held together by calc-spar, is from the cliffs at Kemp Town; and affords a proof that in periods very remote, the same process was in action along the Sussex shores. These beautiful slabs of marble are portions of stalagmites, from St. Michael's Cave, Gibraltar; and this large conical mass, which has been cut through and polished to show its structure, was dug up on the summit of Alfriston-Hill, in Sussex, and must have been formed in some chalk cavern, of which no traces now remain.

47. CONSOLIDATION OF SAND, AND LOOSE MATERIALS.—The changes effected by this process in strata composed of loose materials, are of still greater importance; for by an infiltration of crystallized carbonate of lime, sand is converted into sand-stone,—fragments of soft chalk are transmuted into a solid rock, as in the Coombe-rock of Brighton,—and accumulations of beach, and gravel, into a hard conglomerate, as in this example of the ancient shingle bed of the cliffs, at Rottingdean,—shells, into a building stone, as in this mass from Florida,—and broken corals, into limestone, as in these specimens from Bermuda. By this agency, the bones of animals become permeated with calcareous spar, and the medullary cavities lined with crystals of carbonate of lime: and clay, which has cracked by drying, has its fissures filled up, and becomes consolidated into those curious masses, called *septaria,* which when polished, form the beautiful slabs for which Weymouth is so celebrated.

48. DESTRUCTION OF ROCKS BY CARBONIC ACID GAS.—Although, in the instances cited above, water by its combination with carbonic acid, occasions the solidification of loose and porous beds of detritus, yet the effect of this gas on certain rocks is that of disintegration; for by its solvent influence on the felspar, granite itself is reduced to a friable state; the quartz and mica, which with felspar constitute

granite, being set at liberty. The disintegration of granite, is a striking feature throughout extensive districts in Auvergne, especially in the neighbourhood of Clermont. In the ancient shingle of the cliffs at Kemp Town, near Brighton, blocks of granite occur which may be crumbled to pieces between the fingers. I have already shown you masses of pebbles held together by calcareous spar, from the same locality; we have, therefore, examples in that ancient bed, both of the conservative and disintegrating effects of carbonic acid—cementing the loose beach into solid blocks by calcareous depositions; and, when in a gaseous state, or combined with water, dissolving the granite by its action on the felspar.

49. Carbonic acid gas in caves and wells.—The escape of carbonic acid through fissures, into mines, wells, and caverns, is of frequent occurrence; and as the specific gravity of this gas is greater than that of atmospheric air, it occupies the bottom of these cavities, and its presence is seldom suspected till shown by its deleterious effects; it is called choke-damp by miners. Fatal accidents often happen to well-diggers and excavators from this cause.

The Grotto del Cane, near Puzzuoli, four leagues from Naples, has for centuries been celebrated on account of the carbonic acid gas, containing in combination much aqueous vapour, which is constantly rising from fissures in the rock, and is condensed by the coldness of the external atmosphere. The floor of the cavern being lower than the entrance, the gas is spread over the bottom like a pool of water, and the upper part is free from any noxious vapour. The deleterious effects of the carbonic acid is, therefore, not felt by any creature whose organs of respiration are above the level of this mephitic lake; but if a dog, or other small animal, enter the cave, it instantly falls senseless, and would expire if not speedily removed: the name of the cave is obviously derived from the experiment being often made on dogs, for the amusement of visitors.* It is impossible to fire a pistol at the bottom of the cavern; for, although gunpowder may be exploded even in carbonic acid by the application of a heat sufficient to decompose the nitre, and consequently to envelope the mass in an atmosphere of oxygen gas, yet the influence of a mere spark from steel produces too slight an augmentation of temperature for this purpose.†

50. Consolidation of loose strata by iron.—Water charged with a large proportion of iron, acts an important part in the consolidation of loose materials, converting sand into iron-stone, and beach or shingle into a ferruginous conglomerate. At Clapham Common, and other places in the vicinity of London, a very compact breccia occurs in large blocks, being composed of chalk-flints, more or less broken, and rolled, cemented together by

* See Sandys' Travels. † Daubeny on Volcanoes.

an infiltration of iron. In this example of a horse-shoe firmly impacted in a mass of pebbles and sand, from the sea-beach at Eastbourn, the cement which binds the mass is derived from the iron. Nails are frequently found in the centre of a nodule of hard sandstone formed by this process; the nail having supplied the water with the material by which the surrounding sand has become changed into stone. I have here a cannon ball imbedded in the centre of a nodule of iron-stone, in which are several oyster shells: this specimen was dredged up off the Sussex coast, and has evidently been consolidated by the solution of iron afforded by the partial oxidation of the cannon ball. In this very interesting mass of breccia,* which has been produced by a like process, are two silver pennies of Edward I. This curious specimen, for which I am indebted to George Grantham, Esq. of Barcombe Place, Sussex, was obtained from a Dutch vessel, which was stranded off Hastings a century ago; it is a conglomerate of glass beads, knives,

* This specimen was dug up at a depth of ten feet in the bed of the river Dove, in Derbyshire; and the coins are presumed to be part of the treasures contained in the military chest of the Earl of Lancaster, which was lost in crossing the river in the dark; the guards being alarmed by a sudden panic, and the chest with all its contents thrown into the Dove. The Earl of Lancaster was beheaded in March 1322: the specimen was discovered about six years since; more than five centuries have, therefore, elapsed since its submersion.—*See the Vignette of the Title-page*, vol. i.

and sand; the cementing material having been derived from the oxidation of the blades. In the bed of the Thames, large masses of a ferruginous conglomerate are occasionally found, in which Roman coins, and fragments of pottery, are imbedded; the stone being formed of sand and clay impregnated and consolidated by ferruginous infiltration.

These specimens of oxide of iron were dug up in a marshy soil, near Bolney, in Sussex, and are of the same nature as the substance called bog-iron ore, which so frequently occurs in peat. The ebony colour of the woods from Ireland, which we have already examined, has been derived from an impregnation of iron. Specimens of bog-iron are not uncommon in the superficial loam and gravel of the south-east of England.

The consolidation of sand and other loose materials by these agencies, is taking place everywhere; on the shores of the Mediterranean; on the coasts of the West India Islands, and of the Isle of Ascension; and on the borders of the United States; thus the remains of man, at Guadaloupe — of turtles, in the Isle of Ascension — of recent shells, and bones of ruminants, at Nice—of ancient pottery in Greece—and of animal and vegetable substances, in our own country, have become imbedded and preserved.

I now proceed to notice a few instances of these interesting and important operations, by which much of the solid crust of the globe is continually being renewed.

51. Recent formation of marine limestone in the Bermudas.—The valuable series of specimens before me (presented by W. D. Saull, Esq.) is from the Bermuda Islands, and affords examples of this class of deposits in different states of consolidation. The sea which surrounds the Bermudas abounds in corals and shells; and from the action of the waves on the reefs, and on the dead shells, the water becomes loaded with calcareous matter. Much of this detritus is, no doubt, carried down to the profound depths of the ocean, and there envelopes the remains of animals and vegetables, thus forming new strata for the use of future ages; but a great proportion is borne by the waves towards the shores, and deposited in the state of fine sand. This sand is drifted inland by the winds, and becomes more or less consolidated by the percolation of water, and the infiltration of crystallized carbonate of lime; a fine white calcareous stone is thus formed, which in some localities is sufficiently compact for building. Imbedded in this limestone are numerous shells and corals, of the species which inhabit the neighbouring seas: in some instances the large mottled trochus, so well known to collectors both in its natural and polished state, with all its colours preserved, is imbedded in a pure, white limestone; in many specimens the colours are faded, and the shells very much in the state of

those found in the tertiary strata at Grignon—in others the shelly matter is wanting, but the hard limestone retains the forms and markings of the originals. The corals are imbedded in a similar manner; and masses occur in the limestone so like the fossil corals of the oolite of this country, that it requires an experienced eye to detect their real nature.

In a suite of specimens, showing the transition from loose sand to a solid rock, we have—

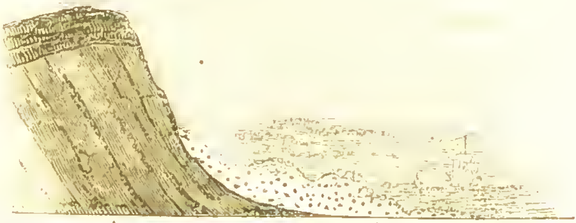
1. Broken shells and corals, retaining their colours.
2. Similar materials, more comminuted and completely bleached.
3. An aggregation of fine sand, broken shells, and corals.
4. Coarse friable limestone, resembling soft chalk, and composed of comminuted corals, &c.
5. Hard limestone, of similar materials.
6. Compact limestone, enveloping shells and pebbles.
7. A fine indurated limestone, so hard as to be with difficulty broken by the hammer, inclosing a few shells, and corals: this stone is employed for building.

Mr. Lyell has described a fresh-water limestone, containing recent shells and aquatic plants, which is in the progress of formation in the lakes of Forfarshire, in Scotland.* In the specimens before us, which were collected by Mr. Lyell, are various

* Geological Transactions, vol. i. p. 73, new series.

species of fresh-water shells, and masses of that common lacustrine plant, the *Chara medicaginula*, beautifully preserved; even the minute seed-vessels of the chara are found converted into stone, in precisely the same manner as those which occur in the ancient fresh-water tertiary limestones. Here then is an example of the formation of a modern lacustrine rock; while, in the deposits at Bermuda, we have proof that the sea is, at this time, producing effects analogous to those which have given rise to many of the ancient secondary strata.

52. FOSSIL HUMAN SKELETONS OF GUADALOUPE.—Similar formations are in progress along the shores of the whole West Indian Archipelago; and in St. Domingo they have greatly extended the plain of Cayes, where accumulations of conglomerates occur, and in which, at the depth of twenty feet, fragments of ancient pottery have been discovered.




TAB. 9.—PLAN OF THE CLIFFS AT GUADALOUPE.

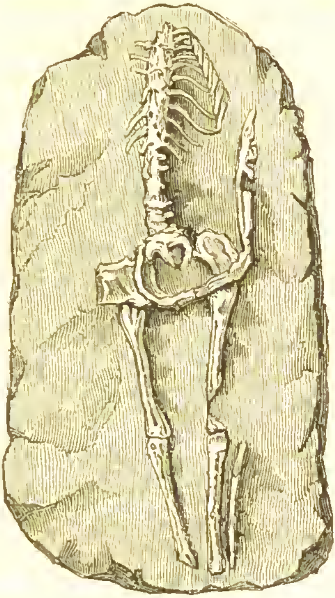
*A, Ancient rocks; B, recent limestone, in which human skeletons are found imbedded.*

On the north-east coast of the main land of Guadaloupe, a bed of recent limestone forms a sloping bank, or glacis, from the steep cliffs of the island to the sea, and is nearly all submerged at high tides. This modern rock is composed of consolidated sand, and comminuted shells and corals, of species now inhabiting the adjacent seas. Land shells, fragments of pottery, stone arrow-heads, carved stone and wooden ornaments, and human skeletons, are found therein imbedded. This being the only known undoubted instance of the occurrence of human bones in solid limestone, has excited great attention; and the fact, simple and self-evident as is its history, has been made the foundation of many vague and absurd hypotheses.

In most instances the bones are dispersed; but a large slab of rock, in which a considerable portion of the skeleton of a female is imbedded, is preserved in the British Museum, and has been described by Mr. Konig, in a highly interesting memoir in the Philosophical Transactions, of 1814.

The annexed representation (TAB. 10.) will serve to convey an idea of this celebrated relic, which was detached from the rock at the Mole, near Point-a-Pitre.

In this specimen the skull is wanting, but the spinal column, many of the ribs, the bones of the left arm and hand, of the pelvis, and of the thighs and legs, remain. The bones still contain some animal matter, and the whole of their phosphate of lime. It is remarkable, that the fragments of the skull of this very specimen have recently been purchased for the museum at South Carolina,

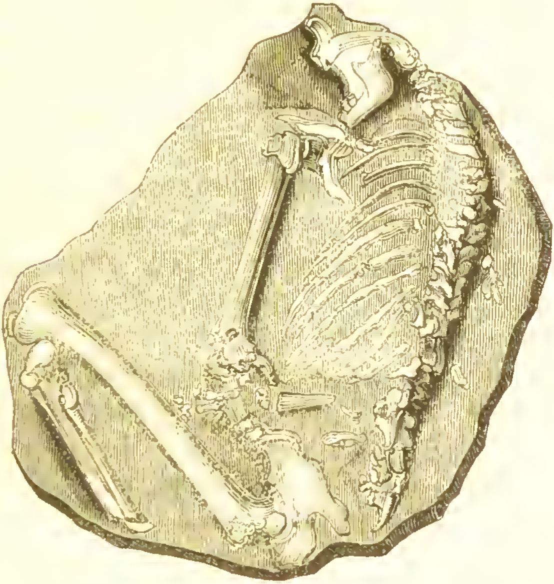


TAB. 10.—FOSSIL HUMAN SKELETON, FROM GUADALOUPE.

*In the British Museum; size of the original, 4 feet 2 inches by 2 feet.*

of a French naturalist, who brought them from Guadaloupe; and they have been described by Professor Moultrie, of the Medical College of that State. These relics consist of portions of the *temporal*, *parietal*, *frontal*, *sphenoidal*, and inferior *maxillary* bones, of the right side of the skull. An entire skeleton was also discovered in the usual position of burial; another, which was in a softer sandstone, was in a sitting posture. The bodies, thus differently situated, may have belonged to distinct tribes. General Ernouf, who carefully investigated this interesting deposit, conjectured that the presence of the bones might be explained by the circumstance of a battle, and the massacre of a tribe of Gallibis by the Caribs, having taken place near this spot, about 120 years ago, and the bodies of the slain been interred on the shore; the skeletons having subsequently been covered by sand-drift, which has been converted into limestone. Dr. Moultrie, however, from a rigorous examination, and comparison of the bones of the skull in his possession, is of opinion, that the specimen in the British Museum did not belong to an individual of the Carib, but to one of the Peruvian race, or of a tribe possessing a similar craniological development.

In another skeleton from Guadaloupe, now in the museum of the *Jardin des Plantes*, and represented in the last edition of Cuvier's *Théorie de la Terre*, the figure is bent, the spine forms an arc, and the thighs are drawn up as if the individual were in a sitting posture; a portion of the upper jaw, and the left half of the lower, with several teeth, nearly the whole of one side of the trunk and pelvis, and a considerable portion of the upper and lower left extremities, are preserved (TAB. 11). The stone is a travertine (page 58), and incloses terrestrial and marine shells; it is evident that the former have been drifted by streams from the interior, and the latter deposited by the ocean. In the bed from which this block was extracted, were found teeth of the *caiman* (a species of crocodile),



TAB. 11.—HUMAN SKELETON FROM GUADALOUPE.
*In the Museum at Paris.*

stone hatchets, and a piece of wood, having rudely sculptured on one side a mask, and on the other the figure of an enormous frog: it is of guaiacum, but has become extremely hard, and as black as jet.

53. IMPRESSIONS OF HUMAN FEET IN SANDSTONE. — In connexion with the occurrence of human bones in limestone, I will here notice a discovery of the highest interest, but which has not,

as yet, excited among scientific observers the attention which its importance demands. I allude to the fact announced in the American Journal of Science, (vol. v. for 1822,) of impressions of human feet in sandstone, discovered many years ago in a quarry at St. Louis, on the western bank of the Mississippi.

TAB. 12.—IMPRESSIONS OF HUMAN FEET IN SANDSTONE.

The above figure is an exact copy of the original drawing, and exhibits the impressions of the soles of two corresponding human feet, placed at a short distance from each other, as of an individual standing upright, in an easy position. The prints are described as presenting the perfect impress of the feet and toes, exhibiting the form of the muscles, and the flexures of the skin, as if an accurate cast had been taken in a soft substance. They were at first supposed to have been cut in the stone by the native

Indians, but a little reflection sufficed to show that they were beyond the efforts of those rude children of nature; since they evinced a skill, and fidelity of execution, which even my distinguished friend, Sir Francis Chantrey, could not have surpassed. No doubt exists in my mind, that these are the actual prints of human feet in soft sand, which was quickly converted into solid rock by the infiltration of calcareous matter, in the manner already described. The length of each foot is ten inches and a half, the spread of the toes four inches, indicating the usual stature; and the nature of the impression shows that the feet were unconfined by shoes or sandals. This phenomenon, unique of its kind, is fraught with so much importance, that I have requested Professor Silliman to ascertain the nature of the sandstone, and the period of its formation. Hereafter I shall have to direct your attention to impressions of another kind, in rocks of immense geological antiquity.

54. Isle of Ascension.—This island, which is a volcanic cone in the midst of the Atlantic, appears to have been a dome of trachytic rocks, subsequently affording vent to lava currents; and its shores are bounded by a conglomerate formed of sand with comminuted shells, corals, echini, and fragments of lava. In the suite of specimens before us are portions of this conglomerate in various states of consolidation. They are composed of corals, which still retain their colour; of shells, more or

less broken; and of sand of similar materials; they also eontain pebbles of traehytie and glassy lava. The shores of this island are a favourite resort of turtles, whieh repair thither in immense numbers, and deposit their eggs in the loose sand: the rapid eonversion of the coarse, ealcareous banks into solid stone, oecasions the frequent imbedding, and preservation of the eggs; and there are speeimens in the eabinet of the Geologieal Soeiety, in whieh the bones of young turtles, just on the point of being hatehed, are well preserved.* The eonglomerate of the Isle of Aseension is, as you may observe, prineipally eomposed of eorals. Here we have another example of a roek formed of the calcareous skeletons of those wonderful forms of organie existenee. It is not my intention in this plaee to dwell on the geological ehanges produeed by reeent zoophytes, in the formation of coral reefs, &e., as the examination of the reeent, and fossil eorals, will form the subjeet of a subsequent leeture.

55. DRIFTED SAND.—We have already briefly alluded to the eneroaehments on the land by the drifting of sand-banks, thrown up beyond the reaeh of the tide, and driven by the winds inland; thus effeeting the desolation of whole regions by their slow, but eertain progress. Egypt instantly presents herself to the imagination, with her stupendous pyramids, the sepulehres of a mighty raee of monarehs, and the wonder of the world—her temples,

* See Lyell's Principles of Geology, 5th edit. vol. iii. p. 269.

and palaces, once so splendid and massive, as to bid defiance to the ravages of time — her plains, and valleys, formerly teeming with abundance, and supporting a numerous population — now stripped of her ancient glories, her fairest regions depopulated, and converted into arid wastes,—her cities overwhelmed, and prostrate in the dust—and the colossal monuments of her kings, and the temples of her gods, half buried beneath the sands of the Desert! The drifting of the sands of the Lybian desert by the westerly winds, observes M. De Luc, has left no lands capable of cultivation on those parts of the western bank of the Nile which are not sheltered by mountains; while in Upper Egypt, whole districts are covered by moveable sands, and here and there may be seen the summits of temples, and the ruins of cities which they have overwhelmed. "Nothing can be more melancholy," says Denon, "than to walk over villages swallowed up by the sand of the Desert, to trample under foot their roofs and minarets, and to reflect that yonder were cultivated fields, that there grew trees, that here were the dwellings of men, and that all have now vanished. The sands of the Desert were in ancient times remote from Egypt; and the Oases which still appear in the midst of this sterile region, are the remains of fertile soils which formerly extended to the Nile."*

* See an Essay on the Moving Sands of Africa, in Professor Jamieson's Translation of Cuvier's Theory of the Earth, p. 375.

Mr.

56. SAND-FLOOD, AND RECENT LIMESTONE OF CORNWALL.—On many parts of the shores of Scotland, sand-floods have converted tracts of great fertility into barren wastes: and on the northern coast of Cornwall an extensive district has been covered by drifted sand, which has become consolidated by the percolation of water holding iron in solution, and in some places forms ranges of low mounds, and hills, forty feet high. This sandstone offers a striking and most interesting example of recent formation, and has been described by Dr. Paris, in a memoir which I do not hesitate to characterize as one of the most graphic, and instructive geological essays on modern deposits, that has appeared in this country.* The sand has evidently been drifted from the sea by hurricanes, probably at a very remote period; it is first seen in a slight, but increasing state of aggregation, on several parts of the shore in the Bay of St. Ives. Around the promontory of New Kaye, the sandstone occurs in various states of induration, from that of a friable aggregate, to a stone so compact, as to be broken

Mr. Wilkinson, in a late highly interesting work, questions the correctness of these inferences, as to the extent of the sand-floods, and asserts, that at the present time the alluvial soil on the increase, the deposits from the inundations of the Nile more than counterbalancing the inroads of the sands; and that the land now capable of cultivation in the valley of Egypt is greater than at the time of the Pharaohs.—*Manners and Customs of the Ancient Egyptians*, vol. i. pp. 218—222.

* Appendix E.

with difficulty by the hammer; and which is used in the construction of churches and houses. Upon examining the stone with a lens, it appears to be principally made up of comminuted shells; and it is worthy of remark, that the shelly particles are frequently found to be spherical, from the previous operation of water, and some portions of the rock closely resemble the ancient limestone called *oolite*, which will hereafter come under our notice. The rocks upon which the sandstone reposes are clay, slate, and slaty limestone; and the water effecting their decomposition may have thus obtained the iron, alumina, and other mineral matters by which the loose sand has been converted into sandstone.

The infiltration of water thus impregnated, Dr. Paris observes, is a common and extensive cause of lapidification: at Pendean cove, granitic sand is gradually hardening into breccia, by this process; and in the island of St. Mary, is becoming indurated by the slow action of water impregnated with iron.

57. Silicious depositions.—Silicious earth, or the earth of flint, is another abundant mineral, and constitutes so large a proportion of the rocks and strata, that it is computed to form, either in a pure or combined state, nearly one-half of the solid crust of the globe. The flints from our cliffs, the boulders and gravel on our shores, and the pebbles of agate, quartz, and chalcedony, are

well-known examples of the usual varieties of silex.*

I scarcely need observe, that this nodule of flint, obtained from a neighbouring chalk quarry, has once been in a soft or fluid state; for here we perceive impressions of shells, and of the spines of an echinus deeply imprinted on its surface.† We have already seen that water impregnated with carbonic acid gas is capable of holding lime in solution; and that travertine, limestone, and other calcareous deposits, have originated from this agency; and although, even in the present advanced state of chemical knowledge, we are unacquainted with the

* Here I would digress for a few moments, to notice an opinion which is so generally prevalent, that I may be permitted to assume, that even some of my readers may not be prepared at once to answer the question,—*Do stones grow?* The farmer who annually ploughs the same land, and every year observes a fresh CROP of stones, would probably answer in the affirmative; and the general observer, who had for successive years noticed his gardens and plantations strewed with stones, notwithstanding their almost daily removal, might entertain the same opinion. A moment's reflection, however, will serve to show, that it is impossible stones can be said to grow, in the proper acceptation of the term. Organic bodies grow, because they are provided with vessels by which they are capable of taking up and assimilating particles of matter, and converting them into their own substance; but an inorganic body can only increase in bulk by the addition of extraneous matter to its outer surface; hence stones may be incrusted, or they may become conglomerated together, but they cannot grow.

† *Vide* "Thoughts on a Pebble; or, a First Lesson in Geology." Fifth edition; 1837.

process by which any large proportion of flint can be held in solution by water, yet we have unquestionable proofs, that the solution of silicious earth has been effected by natural processes, on a very extensive scale. At the present moment, Nature, in her secret laboratories, is still carrying on a modification of the same process; and of this fact we have a remarkable instance in the Geysers of Iceland, and in the springs of Carlsbad, in Bohemia. Professor Silliman remarks, that "the sulphuret of silicon, which is the base of silex, is very soluble, and that silicious earth itself is taken up by fixed alkalies, and by fluoric acid; and that these agencies, like most of those which are chemical, are rendered more active by heat." A high temperature therefore appears necessary to enable water to dissolve a large proportion of silex, &c.; hence, we find that the thermal springs of volcanic regions are the principal agents by which silicious depositions and incrustations, are at present produced.

58. The Geysers.—The Geysers, or boiling fountains, of Iceland, have long been celebrated for possessing this property in an extraordinary degree; holding a large proportion of silex in solution, and depositing it, when cooling, on vegetables and other substances, in a manner similar to that in which carbonate of lime is precipitated by the incrusting springs of which we have already spoken. Iceland may be considered as a mass of volcanic matter; the only substances not of volcanic origin in the

whole island, being beds of surturbrand, or bituminous wood, in which occur leaves, trunks, and branches of trees, with clay and ferruginous earth. These strata support alternating beds of basalt, tufa, and lava, which form the summit of the hill in which the vegetable remains occur. The Geysers, of which there are a considerable number, are springs, or rather intermittent fountains of hot water, which issue from crevices in the lava. A fountain of boiling water, accompanied with a great evolution of vapour, first appears, and is ejected to a considerable height; a volume of steam succeeds, and is thrown up with great force, and a terrific noise like that produced by the escape of steam from the boiler of an engine. This operation continues sometimes for more than an hour; an interval of repose of uncertain duration succeeds, after which the same phenomena are repeated. If stones are thrown into the mouth of the cavity, from which the fountain has issued, they are ejected with violence, after a short interval, and again jets of boiling water, vapour, and steam appear in succession. The eruptions of the "great Geyser," witnessed by Sir G. S. Mackenzie,* were preceded by a sound like the distant discharge of heavy ordnance, and the ground shook sensibly; the sound was rapidly repeated, when the water in the basin, after heaving several times, suddenly rose in a large column,

* Travels in Iceland, in the summer of the year 1810, by Sir George Steuart Mackenzie, Bart.

accompanied by clouds of steam, to the height of ten or twelve feet. The column seemed to burst, and sinking down, produced a wave, which caused the water to overflow the basin. A succession of


TAB. 13.—PLAN OF THE GEYSERS.

eighteen or twenty jets now took place, some of which rose to a height of fifty or sixty feet. After the last eruption, which was the most violent, the water suddenly left the basin, and sunk into the pipe in the centre to a depth of ten feet. After a few hours the eruption was repeated; the jets sometimes attaining ninety feet in altitude. The basin of the "great Geyser" is an irregular oval, about fifty-six feet by forty-six, formed of a mound of silicious depositions about seven feet high; the pipe through which the water is ejected being sixteen feet in diameter at the opening, but contracting to ten feet lower down; its perpendicular depth is estimated at sixty feet. Sir G. S. Mackenzie has proposed an ingenious explanation of these phenomena, which the diagram in the preceding page will serve to illustrate. It is supposed that the water from the surface percolates through crevices (Tab. 13, *a*) into a cavity in the rock (*b*), and heated steam, produced by volcanic agency, rises through fissures in the lava (*c c*). The steam becomes in part condensed, and the water filling the lower part of the cavity (*d*) is raised to a boiling temperature, while steam under high pressure occupies the upper part of the chasm. The expansive force of the steam becomes gradually augmented, till at length the water is driven up the fissure or pipe (*e*), and a boiling fountain with an escape of vapour is produced, which continues playing till all the water in the reservoir is expended, and the steam itself escapes with great violence till the supply is exhausted.*

* Travels in Iceland, p. 229.

The silicious concretions formed by these springs cover an extent of four leagues; these are specimens of the more friable varieties, presented me by Professor Babbage. M. Eugene Robert, who has recently visited Iceland, states that this curious formation may be seen, passing by insensible gradations, from a loose friable state, the result of a rapid deposition, to the most compact and transparent masses, in which impressions of the leaves of the birch-tree, and portions of the stems, are distinctly perceptible, presenting the appearance of the agatized woods of the West Indies. Rushes, and various kinds of mosses converted into a white silicious rock, in which the minutest fibres are preserved, also occur; but on the margin of the Geysers, from the splashing of the water, the depositions resemble large cauliflowers; and on breaking these masses, vegetable impressions are often discovered. Numerous thermal springs occupy the valley in the interior of the island, in the midst of which the Geysers are situated. It is evident that these waters arise from deep crevices, in which they have been heated by volcanic fires. The rivers proceeding from the springs often resemble milk in appearance, owing to the argillaceous bole which they take up in their passage among the silicious concretions: such are the white rivers of Olassai. Mount Hecla, like all the mountains of Iceland, is entirely covered with snow, and no smoke appears on its summit. Accumulations of rolled masses of obsidian and pumice-stone form a layer on the flanks of the mountain, thirty feet thick; stems and branches of the birch-tree occur in the midst of this bed; they are the remains of the ancient forests of the island, which the volcanic eruptions have entirely extirpated.*

This modern silicious formation is a fact of great interest and importance. It tells us in language that cannot be mistaken, that the most insoluble and refractory substances may be reduced to a liquid state, and again become consolidated, and assume other modifications, merely by the agency of thermal waters; hence the envelopement of the delicate corals, shells, &c. which are so abundant in flint nodules, is readily explained.

59. Hertfordshire conglomerate, or pudding-stone.—We have before us a collection of conglomerates formed by carbonate of lime; in other words, aggregations of pebbles, sand, shells, and corals, which are cemented together by calcareous spar and by ferruginous solutions: but this specimen is an example of a mass of rounded flint pebbles, imbedded in a siliceous paste, forming the well-known substance called Hertfordshire pudding-stone, which was formerly in much request; for the cement, being as hard and solid as the pebbles themselves, the stones admit of being cut and polished by the lapidary into a great diversity of ornaments. The formation of this rock must have been effected by a stream of siliceous matter flowing into a bed

* Bulletin de la Société Géologique de France.

of gravel, and converting some portions of the loose pebbles into a solid mass, while those parts which the liquid flint did not reach remained in the state of loose water-worn materials. It is not my intention in this lecture to dwell on the silicification * of the remains of animals and plants; it will suffice to remark, that in the silicified woods from the West Indies the most minute vegetable structure may be detected, although the specimens will strike fire with steel.

60. Effects of high temperature.—The phenomena presented to our notice in this investigation of the Geysers of Iceland, lead to the consideration of another agent in the transmutations that take place in the crust of the globe. It must be obvious to every intelligent mind, that beds of unconnected and porous materials can have acquired hardness and solidity only by one of the following processes, namely:—1st, by matter dissolved in a fluid, and afterwards deposited among the porous masses in the manner just described; or, 2dly, by the reduction of the materials by heat into a state of softness or fusion, and their subsequent conversion, by cooling, into a solid mass.† Fire—or to speak more correctly, a high temperature, however induced, whether by electro-magnetic influence, or proceeding from central or medial sources of heat—and water, are therefore the great agents by which the mineral masses composing the crust of our

* Petrifaction by flint. † Playfair.

planet have been and are still being modified. We have already seen how vast are the changes which result from the effects of water; we must now take a rapid survey of the influence which caloric is capable of exerting; an influence far more universal and varied than we may at first be prepared to expect. The expansive power which heat exerts on most substances, and its conversion of the most solid and durable bodies, first into a fluid, and lastly into a gaseous state, are phenomena so familiar as to require no lengthened comment. But the effects of heat are found to vary according to the circumstances under which bodies are submitted to its operation, and hence the changes induced by high temperature beneath great pressure, are totally different from those effected by fire on the surface, under the ordinary weight of the atmosphere. A familiar example will serve to illustrate my meaning. Chalk consists of lime combined with carbonic acid; and as for agricultural, and other economical purposes, it is desirable to have the lime in its pure state, the chalk, or limestone, is exposed to a great heat, in kilns erected in the open air, until all the carbonic acid gas is dissipated, and the stone is said to be burnt into quick-lime. In the specimens before us, the same substance is seen in the state both of chalk and lime. It may readily be conceived, that if this operation were conducted beneath such a degree of pressure as would prevent the escape of the gas, the formation of quick-lime would not take place;

the chalk would be fused, and the carbonic acid, released from its present relation with the calcareous particles, would enter into other combinations, and the mass when cooled, be wholly different from the product of the lime-kilns, formed by the same agency in the open air. Experiments have proved that this opinion is correct. Sir James Hall exposed pounded chalk to intense heat, under great pressure, and it was fused, not into lime, but into crystalline marble: even the shells inclosed in the chalk underwent the same transmutation, yet preserved their forms. That analogous changes have been effected by natural operations we have abundant proof; but in this stage of our inquiry it is only necessary to remark, that where ancient streams of lava have traversed chalk, the latter invariably possesses a crystalline structure. We shall hereafter find, in accordance with the beautiful and philosophical theory of Dr. Hutton, that all the strata have been more or less modified by heat, acting under great pressure and at various depths; and that the present position and direction of the materials composing the crust of the globe, have been produced by the same cause.* The Huttonian theory, indeed, offers a most satisfactory explanation of a great proportion of geological phenomena, enabling us to solve many of the most difficult problems in the science; and it is but an act of justice to the memory of an

* See Playfair's Illustrations of the Huttonian Theory, vol. i. p. 33, *et seq.* Edin. 1822.

illustrious philosopher, and of his able illustrator, Professor Playfair, to state that this theory, corrected and elucidated by the light which modern discoveries have shed upon the physical history of our planet, is that embraced by the most distinguished modern geologists.

61. VOLCANIC AGENCY.—Of the activity and power of the agent to which these remarks more immediately refer, the currents of melted rocks, called lavas, ejected through crevices and fissures of the earth, accompanied with evolutions of heat and vapour, afford the most striking proofs; and the volcano, with its frequent concomitant the earthquake, have in all ages excited the astonishment and curiosity of mankind. It would be foreign to the design of this discourse, to enter at large upon the nature and causes of volcanic action. Dr. Daubeny,* Mr. Scrope,† and others, have published highly interesting treatises on the subject; and Mr. Lyell has given an admirable sketch of volcanic phenomena.‡ I will only advert to the increased temperature of the earth in proportion as we descend from the surface towards the interior, and the profound depths from which thermal waters take their rise, as tending to support the opinion, that volcanic eruptions are occasioned by electro-chemical changes, which are constantly

* Daubeny's Lectures on Volcanoes, 1826.

† Scrope's Considerations on Volcanoes, 1825.

‡ Principles of Geology, vol. ii.

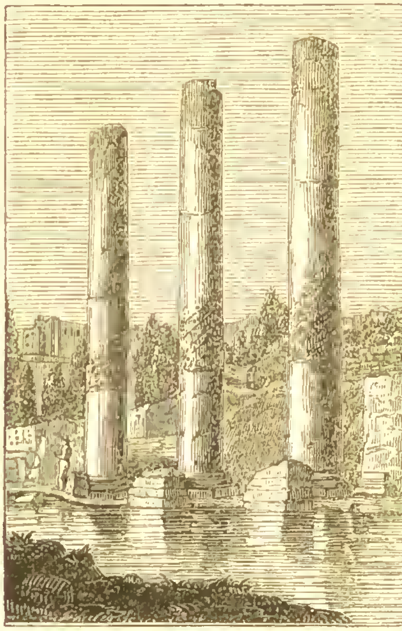
going on in the interior of the globe. We shall hereafter have occasion to demonstrate that dislocations of the strata, with elevations of the bottom of the ocean, and eruptions of melted mineral matter, have taken place from the earliest geological periods within the scope of our inquiries.

62. Expansion of rocks by heat.—The expansive power of caloric, even in ordinary circumstances, is very considerable, as is shown by the instrument called a *pyrometer*, which illustrates a fact continually presented to our notice, namely, the expansion of a bar of metal by heat, and its contraction, by cooling, into its original dimensions. The expansion of solid bodies by heat, when effected on a large scale, gives rise to many interesting phenomena. The careful experiments made by Colonel Totten, on the expansion of granite, marble, and other rocks, by variations of temperature, have shown that the mere expansion, or contraction, of extensive beds of these materials, will account for the elevation and subsidence of considerable tracts of country, and explain many analogous phenomena.*

63. Temple of Jupiter Serapis.—One of the most interesting examples of local elevation and subsidence, apparently resulting from this cause, is that afforded by the celebrated remains of the temple of Jupiter Serapis, at Puzzuoli; and which Mr. Lyell, by selecting as the subject of the frontis-

* American Journal of Science, vol. xxii.

piece of his invaluable work, has for ever associated with the Principles of Geology.



TAB. 14.—TEMPLE OF JUPITER SERAPIS.
*(From Mr. Lyell's Principles of Geology.)*

These ruins are situated on the shore of the Bay of Baiæ, and consist of the remains of a large building of a quadrangular form, seventy feet in diameter; the roof of which was supported by twenty-four granite columns, and twenty-two of marble, each formed of a single stone. Many of the pillars are broken and strewed about the pavement, but three remain standing nearly erect, and on these are inscriptions, not traced by the Greeks or Romans, but by some of the simplest forms of animal existence, which have here left enduring records of the physical changes that have taken place on these shores, since man erected the temple in honour of his gods. The tallest column is forty-two feet in height; its surface is smooth and uninjured to an elevation of about twelve feet from the pedestal, where a band of perforations made by a species of marine boring muscle (*Modiola lithophaga*) commences, and extends to the height of nine feet, above which all traces of their ravages disappear.* The perforations, many of which still contain shells, are of a pear shape, and are so numerous and deep as to prove unquestionably that the pillars were immersed in sea-water, at the very time when the base and lower portions were protected by rubbish and tufa; and that the upper parts projected above the waters, and consequently were placed beyond the reach of the *lithodomi*.† The platform of the temple is now about one foot below high-water mark; and the sea, which is only forty yards distant, penetrates the intervening soil. The upper part of the band of perforations is therefore at least twenty-three feet above the level of the sea; and yet it is evident that the columns were once plunged in salt water for a long period. It is equally clear that they have since been elevated to a height of

* See Appendix F.

† *Lithodomi*, from *lithos*, stone, and *demo*, to build.

twenty-three feet, still maintaining their erect position, amid the extraordinary changes which they have undergone, and incontrovertibly proving that the relative level of the land and sea, on that part of the coast, has changed more than once since the christian era; each movement, both of subsidence and elevation, having exceeded twenty feet.* Yet there, at the present moment, are the remains of that temple—

> "Whose lonely columns stand sublime,
> Flinging their shadows from on high,
> Like dials, which the wizard Time
> Had raised to count his ages by!" †

Professor Babbage attributes the tranquil elevation and depression of the temple, to the contraction and expansion of the strata on which it was built. The sources of volcanic action in the surrounding country are very numerous, and a hot spring still exists on the land-side of the ruins. The change of level is therefore easily accounted for, by supposing the temple to have been built on the surface when the rocks were expanded by the effects of a high temperature, and that they subsequently contracted by slow refrigeration. When this contraction had reached a certain point, a fresh accession of heat from the neighbouring volcano increased the temperature of the strata; which again expanded and raised the ruins to their present level.‡

* Principles of Geology, vol. ii. p. 268.
† Moore. ‡ Appendix G.

Mr. Babbage carries out these views to explain the elevation of continents and mountain ranges, assuming the following facts as the basis of his theory:—

1st. As we descend below the surface of the earth, the temperature increases.

2dly. Solid rocks expand by being heated, but clay and some other substances contract.

3dly. Rocks and strata of dissimilar characters present a corresponding difference as conductors of caloric.

4thly. The radiation of heat from the earth varies in different parts of its surface; according as it is covered by forests, mountains, deserts, or water.

5thly. Existing atmospheric agents, and other causes, are constantly changing the condition of the surface of the globe.

Thus wherever a sea or lake is filled up by the wearing down of the adjacent lands, new beds are formed, conducting heat much less quickly than the water; while the radiation from the surface of the new land will also be different. Hence, any source of caloric, whether partial or central, which previously existed below that sea, must increase the temperature of the strata underneath to a much higher degree than before, because they are now protected by a bad conductor;* and their expansion

* Sir John Herschel observes, that this process is precisely similar to that by which a great coat, in a wintry day, increases the feeling of warmth; the flow of heat outwards being ob-

must therefore elevate the newly-formed deposits above their former level;—thus the bottom of an ocean may become a continent. The whole expansion, however, resulting from the altered circumstances, may not take place until *long* after the filling up of the sea; in which case its conversion into dry land will result partly from the accumulation of detritus, and partly from the elevation of the bottom. As the heat now penetrates the newly-formed strata, a different action may be induced; the beds of clay or sand may become consolidated, and instead of expanding, may contract. In this case, either large depressions will occur within the limits of the new continent, or after another interval, the new land may again subside, and form a shallow sea. This sea may be again filled up by a repetition of the same processes as before;—and thus alternations of marine and fresh-water deposits may occur, having interposed between them the productions of the dry land.*

To review the physical changes which are still taking place around the Bay of Naples would prove highly interesting, but my limits will only permit me to observe, that whole mountains have been elevated on the one hand, and temples and palaces have sunk beneath the sea on the other. In our

structed, and the surface of congelation removed to a distance from the body, by the heat thereby accumulated beneath the new covering.

* Proceedings of the Geological Society, March 1834.

sister island we have evidence of former changes of a like nature, and which are alluded to by our inimitable lyric poet, in the following beautiful lines :—

On Lough Neagh's banks as the fisherman strays,
  When the clear cold eve's declining,
He sees the round towers of other days,
  In the wave beneath him shining!

Thus shall memory often, in dreams sublime,
  Catch a glimpse of the days that are over;
Thus, sighing, look through the waves of time
  For the long faded glories they cover!

64. ELEVATION OF THE COAST OF CHILI.—One of the most remarkable modern instances of the elevation of an extensive tract of country, is that recorded by Mrs. Maria Graham,* as having been produced by the memorable earthquake which visited Chili in 1822, and continued at short intervals till the end of 1823. The shocks were felt through a space of 1,200 miles, from north to south. At Valparaiso, on the morning of the 20th of November, it appeared that the whole line of coast had been raised above its level; an old wreck of a ship, which could not previously be approached, was now accessible from the land; and beds of scallops were brought to light, which were not before known to exist. "When I went to examine the coast," says Mrs. Graham, "although it was high-water, I found the ancient bed of the sea laid

* Now Mrs. Calcott.

bare and dry, with oysters, muscles, and other shells, adhering to the rocks on which they grew: the fish being all dead, and exhaling the most offensive effluvia. It appeared to me, that there was every reason to believe the coast had been raised by earthquakes at former periods, in a similar manner; for there were several lines of beach, consisting of shingle mixed with shells, extending in parallel lines to the shore, to the height of fifty feet above the sea." * Part of the coast thus elevated consists of granite; and subsequent observations have proved that the whole of the country was raised, from the foot of the Andes to far out at sea; the supposed area over which the elevatory movements extended, being about 100,000 square miles; a space equal in extent to half the kingdom of France. Mrs. Somerville mentions, that a further elevation to a considerable extent has also taken place along the Chilian coast, in consequence of the violent earthquake of 1835.

65. Lifted sea beach at Brighton.—Examples of such changes occur in almost every part of the world; and there is perhaps no considerable extent of country which does not afford some proof that similar physical mutations have taken place in modern times. And although I cannot point out to you a temple of Serapis on our shores, yet within a few hundred yards of Brighton, there is unquestionable evidence that the relative level of land

* Geological Transactions, vol. i. second series.

and sea, has undergone great changes within, to speak geologically, a comparatively recent period. The upper part of the cliffs, extending from the commencement of the low range by Shoreham, to Rottingdean, is composed of chalk with rubble, flints slightly rolled, and clay and loam; the whole being clearly an accumulation of water-worn materials, deposited in an estuary or bay of the sea. The base of the cliffs, to the height of a few feet, is composed of the solid chalk, which may be seen at low water extending far out to sea, and is covered here and there by shingle and sand. Between the chalk and the superincumbent mass just described, is a bed of shingle, composed of rolled chalk, flints, pebbles, and sand, with boulders of granite, porphyry, and other rocks, not now met with on those shores; in fact, an ancient sea beach, formed at some remote epoch, in like manner as the present bed of shingle, which skirts the base of the cliffs, is in the progress of formation. Among the pebbles of this ancient beach, are rolled masses of chalk and limestone, which are full of perforations made by boring shells; here are several specimens, which are similar to those made in the chalk-rock by the recent *pholades* and *mytili*. As I shall have occasion to revert to these cliffs in the next lecture, this brief description will suffice for our present purpose.

The following diagram represents a natural vertical section of the cliffs, as seen in those parts where the inroads of the sea have extended to the chalk strata, and the face of the ancient cliff is


Tab. 15.—Elevated beach at Brighton, east of Kemp Town.

A, *Elephant bed;* B, *ancient bed of shingle;* C, *the chalk.*

exposed, the new deposits being shown in profile; these consist of the following beds:—

1. (A) Chalk, rubble, loam, &c., obscurely stratified; this deposit, from its containing teeth and bones of elephants, is called the Elephant-bed; it constitutes the upper three-fourths of the cliffs.

2. (B) Shingle, or sea beach and sand, many feet above high-water mark. This ancient shingle, which from the inroads of the sea extends in the cliffs beyond Kemp Town but a short distance inland, is constantly found beneath the loam and clay, several hundred yards from the shore in the western part of Brighton. In a well lately dug in the Western road, the shingle bed was reached at the depth of fifty-four feet.

3. (C) The undisturbed chalk, which forms a sloping cliff, inland, or behind the beds (A) and (B), passes under the ancient sea beach, and appears as a terrace at the foot of the present cliffs.*

These appearances demonstrate the following sequence of changes in the relative level of the land and sea on the Sussex shores:—

*First.* The chalk terrace on which the ancient shingle rests, was on a level with the sea for a long period; and the beach was formed, like the modern beach, by the action of the waves on the then existing cliffs. The rolled condition of the materials, and the borings of the *lithodomi*, prove a change of level as decidedly as do the perforations in the columns of the temple of Serapis.

*Secondly.* The whole line of coast, with the shingle (B), was submerged to such a depth, as to admit the deposition of the strata (A) above them.

*Lastly.* The cliffs were raised to their present elevation, and at this period the formation of the existing sea beach commenced.

The elevation of the sea-shore with beds of marine shells, already alluded to as having been produced by earthquakes on the Chilian coast, has here then a parallel. A phenomenon of a like nature, but of a far more ancient period, is observable at Castle Hill, near Newhaven, about eight miles east of Brighton, where is seen immediately beneath the

* See Geology of the South-East of England, p. 30; and Fossils of the South Downs, p. 277.

turf, a regular sea beach with beds of oyster-shells, many feet in thickness, lying on the summit of the chalk cliffs, 150 feet above the level of the sea. Near Bromley, in Kent, and at Reading, in Berkshire, similar accumulations of beach and oyster-shells are to be found. Elevated shingles, of comparatively recent epochs, occur on the shores of the Frith of Forth, and also along the western coasts of England, as Mr. Murchison has satisfactorily demonstrated.

66. Elevation of Scandinavia. — Having thus adduced a few striking proofs of the mutations which the land has undergone in past times, we are led to enquire—Is this change still going on? Is the alternate subsidence and elevation of the land the effect of a law of nature, established from the existence of the present condition of our planet, and destined to continue in action while its physical constitution remains the same? We shall hereafter find, that this law has been in constant action from the earliest periods of the earth's history, of which her physical monuments afford any indications; and I now proceed to adduce an instance in which the elevation of a whole country is actually taking place, unheeded by the busy multitude, and known only by the researches of the natural philosopher. I allude to Scandinavia, which, it is ascertained, is slowly and visibly rising, from Frederickshall, in Sweden, to Abo, in Finland, and even, perhaps, as far as St. Petersburgh; while the adjacent coast of

Greenland is suffering a gradual depression. The state, therefore, is one of oscillation, the waters appearing to sink at Torneo, and to retain their former level at Copenhagen. The opinion that Sweden is in this state of change, is no new idea; it was long since noticed by Celsius,* and other Swedish philosophers. Mr. Lyell has twice visited Scandinavia within the last few years, with the view of determining this interesting question; and has fully convinced himself that certain parts of Sweden are undergoing a gradual rise, to the amount of two or three feet in a century; while other parts, farther to the south, appear to have experienced no movement.† He visited some parts of the shores of the Bothnian Gulf, between Stockholm and Gefle, and of the western coasts of Sweden, districts particularly alluded to by Celsius. He examined the marks cut by the Swedish pilots, under the direction of the Swedish Academy of Sciences, in 1820, and found the level of the Baltic, in calm weather, to be several inches lower than the marks, and several feet below those made seventy or a hundred years ago. Similar results were obtained on the side of the ocean, and in both districts the testimony of the inhabitants agreed with that of their ancestors, recorded by Celsius. On the shores of the Northern Sea, there are banks of recent shells,

* Illustrations of the Huttonian Theory, p. 436, edit. 1822.

† Philosophical Transactions. Principles of Geology, Fifth Edition, vol. ii. p. 286.

at various heights, from 10 to 200 feet, and on the side of the Bothnian Gulf, between Stockholm and Gefle, deposits containing fossil shells of the species which now inhabit the brackish waters of that sea. These occur at various elevations, from one to a hundred feet, and sometimes extend fifty miles inland. The shells are partly marine and partly fluviatile; the marine species are identical with those now living in the ocean, but are dwarfish in size, and never attain the average dimensions of those which live in water sufficiently salt to enable them to reach their full development. The specimens before you were collected by Mr. Lyell at Uddevalla, in Sweden, from the summit of cliffs twenty feet above the level of the sea; they consist of recent marine species, such as inhabit the neighbouring waters.

Of the reality of these changes in the relative level of the land and of the Northern ocean, there cannot exist a doubt; but the mind is so accustomed to associate the idea of stability with the land, and of mutability with the sea, that it may be necessary to offer a few additional remarks on these highly interesting facts. As it is the property of all fluids to find their own level, it is obvious that if the level of the sea be elevated or depressed in any one part, that elevation or depression must influence the whole surface of the ocean, and the level therefore cannot be affected by local causes. But movements of the land may take place, and the effect extend over whole countries, as in South America,—or along lines of coast, as in Sussex,—or be confined to a single island,—or even to the broken columns of a temple, as at Puzzuoli.* But while the land is rising in the more northern latitudes, it appears to be sinking on the shores of the Mediterranean. Breislak mentions † that numerous remains of buildings are to be seen in the Gulf of Baiæ; ten columns of granite, at the foot of Monte Nuovo, are nearly covered by the sea, as are the ruins of a palace built by Tiberius in the island of Caprea. Thus, while the level of the sea is becoming lower in the north, it is *rising* in the Mediterranean; and as all the parts of the ocean communicate, the sea cannot permanently rise in one part and sink in another, but must rise and fall equally to maintain its level; we must therefore consider it as demonstrated, that these changes have proceeded from the elevation and depression of the land. If we bear in mind the insignificance of the masses affected by these operations, as contrasted with the earth itself (see page 14), we may readily conceive that as fissures and inequalities are produced in the varnish of an artificial globe by heat and cold, in like manner the elevation of mountain chains, the rending of extensive tracts of country, and the subsidence of whole continents, may be occasioned by

* See Playfair's admirable comments on this geological problem.—*Illustrations*, p. 433.

† Playfair.

the expansion and contraction of the materials of which our planet is constructed.

67. Retrospect.—In this imperfect sketch of the geological phenomena, which a superficial examination of the surface of the globe presents to our notice, I have doubtless dwelt on several subjects which are familiar to many of my auditors. But, as one of our ablest geologists* has remarked, "the teacher of Geology must suppose himself called on to answer questions both concerning the facts of the science and the inferences to be deduced therefrom; and his instructions will be so much the more successful as he takes these questions in the most natural order of their occurrence, and answers them most completely and satisfactorily. In doing this he is not at liberty to neglect even elementary truths, for if these were passed over in compliment to such as have made progress in the science, those for whose advantage he is especially interested, would be called to the unreasonable task of labouring without instruments, and of theorizing without intelligible data."

From the vast field of inquiry over which our observations have extended, it may be useful to offer a brief summary of the leading principles that have been enunciated, and the facts on which they are founded. By the most profound and sublime investigations of which the human mind is capable, we learn that our earth is one of myriads of

* Professor Phillips.

spherical bodies, revolving round certain luminaries; and that these bodies occur in every variety of condition, from that of a diffuse luminous vapour, to opaque solid globes like our own. All the materials of which the earth is composed may exist either in a solid, fluid, or gaseous state; and simply by a change of temperature, or by electro-chemical agency, every substance may undergo a transition from one state to the other. Water existing as ice, fluid, or vapour, and separable into two invisible gases, offers a familiar example of a body constantly exhibiting these changes; and mercury, of a metal which, although generally fluid, or melted, becomes, when exposed to a very low temperature, a solid mass like silver. The relative position of land and water, and the inequalities on the surface of the earth, are subject to constant changes, which are regulated by certain fixed laws. The principal causes of the degradation of the land are atmospheric agencies, variations of temperature, and the action of running water, by which the disintegrated materials of the land are carried into the bed of the ocean. The mud, sand, and other detritus thus produced, are consolidated by certain chemical changes which are in constant activity, both on the land and in the depths of the ocean, and new rocks are thus in the progress of formation. But the conjoint effect of these disintegrating agencies is unremitting destruction of the land; and were there no conservative process, the whole of the dry land would disappear, and the earth be covered by one vast sheet of water. The globe, however, possesses an internal source of heat,—and whether this heat exist as a central nucleus of high temperature, or as medial foci,—whether it be dependent on the assumed original nebulous state of the earth, or produced by electro-magnetic forces acting on the mineral substances contained in the interior of our planet,—does not affect the present inquiry. This internal heat, however produced, must occasion constant changes in the relative level of the land and water; elevating whole continents,—converting the bed of the sea into dry land,—and submerging the dry land into the abyss of the ocean. The volcano and the earthquake are the effects of its paroxysmal energies,—the quiet and insensible elevation of the land, of its slow but certain operation. By this antagonist power the accumulation of the spoils of the land, which the rivers, waves, and currents have carried into the bed of the ocean, are again brought to the surface, and form the elements of new islands and continents; and by the organic remains discovered in these strata, we trace the nature of the countries from whence these spoils were derived. In the deltas and estuaries of modern times,—in the detritus accumulating in the beds of the ocean,—in the recent tracts of limestone forming on the sea-shores,—beneath the cooled lava currents erupted from existing volcanoes,—the remains of man and of his works, and of the animals and plants which are his contemporaries, are found imbedded.

The dynamical effects of elevation appear to be referable to three great divisions:—1. The gradual raising up of ridges through large spaces of the earth's crust, and the consequent production of longitudinal fissures and lines of volcanic vent. 2. The long continued protrusion and eruption of igneous rocks along such lines of vent; and 3. Local and partial eruptions and protrusions, producing valleys of elevation, dislocations of the strata, and other phenomena that terminate in ordinary volcanic action.*

Such are the deductions derived from the phenomena which have been submitted to our examination.

To the mind previously uninstructed in geological science, I am ready to acknowledge that to attribute mutability to the rocks and the mountains, must appear as startling and incredible, as did the astronomical doctrines of Galileo to the people of his time. But the intelligent observer, whose attention has been directed to the facts laid before him even in this brief survey, cannot, I conceive, refuse his assent to the inferences thus cautiously obtained. As we proceed in our investigation, we shall find that from the earliest period of the earth's physical history, its surface has been subject to incessant fluctuation; and as the land has been the theatre

* Proceedings of the Geological Society, vol. ii. p. 67.

of perpetual mutation, that element, which has hitherto been considered as the type of mutability, can alone be regarded as having undergone no change. This idea is finely embodied by Lord Byron in the following sublime apostrophe to the Ocean, with which I will conclude this discourse.

"Thy shores are empires, changed in all save thee—
Assyria, Greece, Rome, Carthage, what are they?
Thy waters wasted them while they were free,
And many a tyrant since; their shores obey
The stranger, slave, or savage; their decay
Has dried up realms to deserts:—not so thou,
Unchangeable, save to thy wild waves' play—
*Time writes no wrinkle on thine azure brow—*
*Such as Creation's dawn beheld, thou rollest now!*"

# LECTURE II.

1. Introductory observations. 2. Extinction of animals. 3. Animals extirpated by human agency. 4. The apteryx australis. 5. The dodo. 6. The Irish elk. 7. Epoch of terrestrial mammalia. 8. Character of the ancient alluvial deposits. 9. Classification of mammalian remains. 10. Comparative anatomy. 11. Adaptation of structure in animals. 12. Osteological characters of the carnivora. 13. Structure of the herbivora. 14. Structure of the rodentia, or gnawers. 15. General inferences. 16. Fossil bones. 17. Fossil elephants, or mammoths. 18. Mammoth and rhinoceros in ice. 19. Teeth of recent, and fossil elephants. 20. The mastodon. 21. Mastodons from the Burmese empire. 22. The sivatherium. 23. The megatherium. 24. The megalonyx. 25. The sloth. 26. Fossil hippopotamus, rhinoceros, horse, &c. 27. The dinotherium. 28. Fossil carnivora in caverns. 29. Cave of Gaylenreuth. 30. Forster's Höhle. 31. Bone caverns in England.—Kirkdale cave. 32. Diseased bones of carnivora found in caves. 33. Human bones, and works of art in caverns. 34. Osseous breccia, or bone conglomerates. 35. The rock of Gibraltar. 36. Osseous breccia of Australia. 37. Retrospect.

1. Introductory observations.—In the previous lecture we took a comprehensive view of the actual physical condition of the surface of our planet, and of the nature and results of the principal agents by which the land is disintegrated and renewed. We found in the modern fluviatile and marine deposits, that the remains of man, of works of art, and of the existing races of animals, were preserved. In every step of our progress, the grand law of nature, alternate decay and renovation, was exemplified in striking characters—whether in the

regions of eternal snow, or in torrid climes—in the rocks and mountains, or in the verdant plains—by the agency of heat, or by the effect of cold—of drought, or of moisture—of steam, or of vapour—by the abrasion of torrents and rivers—by inundations of the ocean—or by volcanic eruptions—still the work of destruction, in every varying character, was apparent. And on the other hand we perceived that amidst all these processes of decay and desolation, perpetual renovation was at the same time going on,—and that Nature was repairing her ruins, and accumulating fresh materials for new islands and continents; and that innumerable living instruments were employed to consolidate, and build up the rocky fabric of the earth; and that even the most terrific of physical phenomena, the earthquake, and the volcano, were but salutary provisions of the Supreme Cause, by which the harmony and integrity of our planet were maintained and perpetuated. The occurrence of human skeletons in modern limestone—of coins and works of art in recent breccia—and the preservation of the bones of existing species of animals, and of the leaves and branches of vegetables, in the various deposits that are in progress, incontestably prove that enduring memorials of the present state of animated nature will be transmitted to future ages. When the beds of the existing seas shall be elevated above the waters, and covered with woods and forests—when the deltas of our rivers shall be converted into fertile tracts, and become the sites of towns and cities—we cannot doubt that in the materials, extracted for their edifices, the then existing races of mankind will discover indelible records of the physical history of our times, long after all traces of those stupendous works, upon which we vainly attempt to confer immortality, shall have disappeared. But we must now proceed, and pass from the ephemeral productions of man, to the enduring monuments of nature—from the coins of brass and silver, to the imperishable medals on which the past events of the globe are inscribed—from the mouldering ruins of temples and palaces, to the examination of the mighty relics, which the ancient revolutions of the earth have entombed.

2. Extinction of animals.—Before entering upon the consideration of the geological phenomena, which belong to the period immediately antecedent to the present, it will be necessary to notice one of the most remarkable facts which geological investigations have established,—namely, the entire obliteration of certain genera of animals and plants. The fluctuating state of the earth's surface, with which our previous inquiries have made us familiar, will have prepared us for the disappearance of some species of animals;—and here another law of the Creator is manifest. Certain races of living beings, suitable to peculiar conditions of the earth, appear to have been created; and when those states became no longer favourable for the continuance of such

types of organization, according to the natural laws by which the conditions of their existence were determined, the races disappeared, and were probably succeeded by new forms.

The extinction of whole genera of animals and plants has no doubt depended on many causes. In the earlier ages, the changes of temperature, and the rapid mutations of land and water, were probably the principal agents of destruction; but since man became the lord of the creation, his necessities and caprice have occasioned the extirpation of whole tribes of animals, whose relics are found in the superficial strata, with those of species concerning which both history and tradition are silent.

In this country the beaver, wolf, hyena, bear, &c. are examples of species which, although extinct in Great Britain, still exist elsewhere; while the mammoth, and the Irish elk, whose remains occur in our alluvial deposits, are both extinct; the latter was unquestionably extirpated by the early inhabitants of these islands. The obliteration of certain forms of organization, is therefore clearly dependent on a law in the economy of nature which is still in active operation; and I shall proceed to notice the connecting links between the actually existing species, and those which are blotted out from the face of the earth.

3. Animals extirpated by human agency. —That the extinction of many of the existing races of animals must soon take place, from the immense

destruction occasioned by man, cannot admit of doubt. In those which supply fur, a remarkable proof of this inference is cited in a late number of the American Journal of Science. "Immediately after South Georgia was explored by Captain Cook, in 1771, the Americans commenced carrying seal-skins from thence to China, where they obtained most exorbitant prices. *One million two hundred thousand skins* have been taken from that island alone, since that period; and nearly an equal number from the Island of Desolation! The numbers of the fur-seals killed in the South Shetland Isles (S. lat. 63°,) in 1821 and 1822, amounted to three hundred and twenty thousand. This valuable animal is now almost extinct in all these islands." From the most authentic statements it appears certain that the fur trade must henceforward decline, since the advanced state of geographical science shows that no new countries remain to be explored. In North America the animals are slowly decreasing from the persevering efforts, and the indiscriminate slaughter, practised by the hunters, and by the appropriation to the use of man, of those forests and rivers which once afforded them food and protection. They recede with the aborigines before the tide of civilization.

4. The apteryx australis. — An extraordinary bird, a native of New Zealand, of which but few living individuals are known to naturalists, appears to be on the point of extinction; it is the

*Apteryx Australis*, so called from being destitute of wings. The only known specimen was figured and described by Dr. Shaw, and is now in the collection of Lord Stanley. It has lately been examined by

TAB. 16.—APTERYX AUSTRALIS.

Mr. Yarrell, by whom the characters of the skeleton have been correctly ascertained. This bird is of a greyish brown colour, and has neither wings nor tail. The beak is slightly curved, and the nasal apertures, instead of opening at the base, as in birds in general, and especially in those of a similar conformation of beak, which is adapted for respiration while immersed in mud or water, is placed at the apex. The eyes are very small. The feathers are long and loose, like those of the emu, but each plume has only a single shaft.*

* Since the former edition of this work, three or four dead specimens of the apteryx have been brought from New Zealand to this country. Mr. Gould states that it is a very rare bird, and that its nocturnal habits render it difficult to be obtained. Its skin is in much request among the New Zealand chiefs, to

5. THE DODO (*Didus ineptus*).—A remarkable instance of the extirpation of a peculiar type of organization is afforded by the dodo, which has been annihilated, and become a denizen of the fossil kingdom, almost before our eyes. The dodo was a bird of the gallinaceous tribe, larger than a turkey, which abounded in the Mauritius and adjacent islands, when those countries were first

TAB. 17.—THE DODO.

colonized by the Dutch, about two centuries ago. This bird formed the principal food of the inhabitants, but it was found to be incapable of domestication, and its numbers therefore soon became

ornament their war dresses. Captain Symonds also mentions the apteryx as frequenting Cloudy Bay, and affording excellent sport to the hunters, to whom it is of great value, on account of its feathers, which are held in high estimation among the natives.

sensibly diminished. Stuffed specimens were preserved in the museums of Europe, and paintings of the living animal are still extant in the Ashmolean Museum at Oxford, and in the British Museum. But the dodo is now extinct — it is no longer to be found in the isles where it once flourished ; and even all the stuffed specimens are destroyed. The only relics that remain, are the head and foot of an individual in the Ashmolean, and the leg of another in the British Museum. To render this illustration complete, the bones of the dodo have been found in a tufaceous deposit, beneath a bed of lava, in the Isle of France ; so that if the remains of the recent bird already alluded to, had not been preserved, these fossil relics would have constituted the only proof that such a creature had ever existed on our planet.

6. The Irish elk, or cervus megaceros. (*elk with great antlers.*)—The shell marls of Ireland also afford evidence of the existence of an animal, which, like the dodo, was once cotemporaneous with the human species, but is now altogether extinct, the last individual of the race having, in all probability, been destroyed by man. Its remains commonly occur in the beds of marl beneath the peat-bogs, which are apparently, like those of Scotland, the sites of ancient lakes. In Curragh, immense quantities of the bones of the elk lie within a small space, as if the animals had assembled in a herd : the skeletons appear to be entire, and the

nose is elevated, the antlers being thrown baek on the shoulders, as if the ereatures had sunk in a morass, and been suffoeated. Remains of the elk occur also in marl and gravel, in many parts of England, Franee, Germany, and Italy. This enormous ruminant very far exeeeded in magnitude any living speeies. The skeleton is upwards of ten feet high from the ground to the highest point of the antlers, whieh are palmated, and are from ten to fourteen feet from one extremity to the other. The museum of the late eminent anatomist, Joshua Brookes, whieh, to the disgraee of the government of this eountry, was suffered to be dispersed, eontained a magnifieent pair, measuring eleven feet in expanse, whieh are now in my eolleetion. Skulls have been found without horns, and these probably belonged to females. The average weight of the skull and antlers is eomputed at three quarters of a hundred-weight; they are generally in a fine state of preservation, of a dark brown eolour, with here and there a bluish inerustation of phosphate of iron, like those of the deer from Lewes Levels. The elk shed its horns, and probably, like existing speeies, annually. Professor Jameson, Mr. Weaver, and others, have clearly proved that this majestie ereature was eoeval with man. A skull was diseovered in Germany, assoeiated with urns and stone hatehets; and in the eounty of Cork, a human body was exhumed from a wet and marshy soil, beneath a bed of peat eleven feet thiek; the body was in good preservation, and enveloped in a deer skin covered with hair, which there is every reason to conclude was that of the elk. A rib of the elk has also been found, in which there is a perforation, that evidently had been formed by a pointed instrument while the animal was alive, for there is an effusion of callus or new bony matter, which could only have resulted from something remaining in the wound for a considerable period; such an effect, indeed, as would be produced by the head of an arrow or spear.* There is, therefore, presumptive evidence that the race was extirpated by the hunter-tribes who first took possession of these islands.

Beds of gravel and sand, containing recent marine shells and bones of the Irish elk, have been observed by Dr. Scouler in the vicinity of Dublin, at an elevation of two hundred feet above the level of the sea. It is therefore manifest that this extinct quadruped, although found in peat-bogs and morasses at a comparatively recent period, must have been an inhabitant of Ireland antecedently to some of the last changes in the relative position of the land and water. The discovery of a vast number of skeletons of the elk in the small area of the Isle of Man, seems to indicate a great alteration in the extent of land and sea; for it is difficult to conceive that such herds of this gigantic race could exist in so limited a district; and it is therefore probable that the island was separated from the

* Jameson's Cuvier.

main land at no remote geological period, by subsidences commensurate with the elevation of which Ireland affords such decisive evidence.*

In the remarkable examples just cited, we have an interesting transition from the recent to the lost types of animal existence. 1st, Species extinct in the British islands, but still living in other countries. 2dly, Animals which have been entirely destroyed within the last few centuries. Lastly, Species that were blotted out from the face of the earth by the early races of mankind.

7. Epoch of terrestrial mammalia.—We must now advance another step in the history of the past, and proceed from the consideration of what is known, to that which is unknown; the subsequent divisions of this discourse will be restricted to the geological phenomena of the period immediately antecedent to the present; a period in which the earth appears to have teemed with enormous mammalia, and with which but few species of the existing races were associated. Thus while the present may be termed the *modern* or *human epoch*, that which forms the immediate subject of our investigation may be designated the *epoch of gigantic mammalia*.

8. Character of the ancient alluvial deposits.—"When the traveller," says Cuvier, "passes over those fertile plains, where the peaceful

* Address of Charles Lyell, Esq. President of the Geological Society of London, 1837.

waters preserve, by their regular eourses, an abundant vegetation, and the soil of whieh is erowded by an extensive population, and enriehed by flourishing eities, whieh are never disturbed but by the ravages of war, or the oppression of despotism, he is not inelined to belicve that nature has also had her intestine wars, and that the surfaee of the globe has been overthrown by various revolutions and eatastrophes. But his opinions ehange as he penetrates into that soil at present so peaeeful; or as he aseends the hills whieh bound the plains. His ideas expand, as it were, with the prospeet; and so soon as he ascends the more elevated ehains, or follows the beds of those torrents whieh deseend from their summits, he begins to eomprehend the extent and grandeur of those physieal events of ages long past. Or if he examine the quarries on the sides of the hills, or the eliffs whieh form the boundaries of the oeean, he there sees, in the displacement and contortion of the strata, and in the layers of water-worn materials, teeming with the remains of animals and plants, proofs that those tranquil plains, those smooth unbroken downs, have onee been at the bottom of the deep, and have been lifted up from the bosom of the waters; and everywhere he will find evidence that the sea and the land have eontinually ehanged their plaee."

In almost every part of the world, beneath the modern alluvial soil, the nature and charaeter of which were described in the former lecture, extensive beds of gravel, clay, and loam, are found spread over the plains, or on the flanks of the mountain chains, or on the crests of ranges of low elevation; and in these accumulations of water-worn materials, are immense quantities of the bones of large mammalia.* These remains belong principally to animals related to the elephant, as the mammoth, mastodon, &c., and to various species of hippopotamus, rhinoceros, horse, ox, deer, and many of extinct genera; while in caverns and fissures of rocks filled with calcareous breccia, the skeletons of tigers, boars, hyenas, and other carnivorous animals, are imbedded. Fossil bones of this kind exist, in such abundance, all over Europe, Asia, and America, that it is impossible to enumerate the localities; they are found alike in the tropical plains of India, and in the frozen regions of Siberia; while there is no considerable district of Great Britain in which some traces of these remains do not occur.

9. Classification of mammalian remains.—Dr. Buckland considers these remains as referable to four divisions.

*First.* Land animals, drifted into estuaries or seas, and associated with marine shells, such as those found in the Sub-Apennine formations; in the beds of gravel, sand, &c. provincially termed *crag*, in

* The term *diluvium* is commonly applied to these ancient alluvial beds; they are the newer *pliocene* in the classification of Mr. Lyell, as we shall hereafter explain.

Norfolk and Suffolk; loam and chalk conglomerate in Brighton cliffs; and in clay off Harwich and Herne Bay, and on the coast of Western Sussex.

*Secondly.* Terrestrial quadrupeds, imbedded with fresh-water shells; in strata that have been formed during the same epoch as the above, at the bottom of fresh-water lakes; such are the fossil bones of the lacustrine marls of the Val d'Arno.

*Thirdly.* Similar remains in superficial detritus, spread over the surface of rocks of all ages; as in beds of gravel near London; Petteridge Common, Surrey; near Eastbourn, Sussex, &c.

*Fourthly.* Osseous remains of carnivorous and herbivorous animals in caverns and fissures of rocks which formed part of the dry land, during the later period of the same epoch. The caverns of Gaylenreuth, Kirkdale, &c. are examples.

*Lastly.* The relics in the osseous breccias that occur in fissures of limestone on the shores of the Mediterranean, in the Ionian Isles, in the rock of Gibraltar, at Plymouth, and in the Mendip hills.*

Before I direct your attention to the fossils before us, which have been collected from the alluvial deposits under examination, and from various localities, it will be necessary to review the leading principles of that science which explains the structure of animal existence. Thus while in our preceding investigations we referred to Astronomy to dissipate the obscurity which shrouded the earliest

* Dr. Buckland's Bridgwater Essay, p. 94.

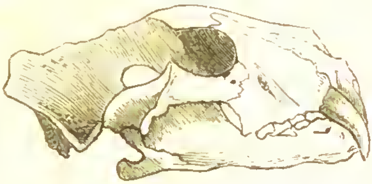
history of our planet, we are now led to that important department of natural knowledge, Comparative Anatomy, to enable us to restore the lost forms of animal existence. I shall therefore explain the mode of induction employed by the scientific observer, in his investigation of the fossil remains of animals, by which he is enabled to ascertain the structure and habits of those creatures which have long since disappeared from the face of the earth.

10. Comparative anatomy. — To a person uninstructed in this science, the specimens before us would appear a confused medley of bones and of osseous fragments, impacted in solid stone; and the only knowledge he could derive from their examination would be the fact, that the stone was once in the state of sand or mud, in which, while soft, the bones had become imbedded. But in vain would he seek for further information from these precious historical monuments of Nature; to him they would appear as unintelligible as were the hieroglyphics of Egypt, before Young and Champollion explained their mysterious import. It is only by an acquaintance with the structure of the living forms around us, and by acquiring an intimate knowledge of their osseous frame-work or skeleton, that we can hope to decipher the handwriting on the rock, obtain a clue to guide us through the labyrinth of fossil anatomy, and conduct to those interesting results, which the genius

of the immortal Cuvier first taught us how to acquire. And here it will be necessary to enter upon the consideration of those beautiful principles of the co-relation of structure in organized beings, which were first announced by that illustrious philosopher.

11. Adaptation of structure in animals. —The organs of every animal, observes M. Cuvier, may be considered as forming a machine, the parts of which are mutually dependent on each other, and exquisitely adapted for the functions they are destined to perform; and such is the intimate relation of the several organs, that any variation in one part, is constantly accompanied by a corresponding modification in another. This mutual adaptation of the several parts of the animal fabric is a law of organic structure, which, like every other induction of physical truth, has only been established by patient and laborious investigation. It is by the knowledge of this law that we are enabled to reassemble, as it were, the scattered remains of the beings of a former state of the globe,—to determine their place in the scale of animated nature,—and to reason on their structure, habits, and economy, with as much clearness and certainty, as if they were still living and before us. I will demonstrate this proposition by a few examples. Of all the solid parts of the animal structure the most obviously mechanical are the jaws and teeth; and as we know in each instance the operations they are intended to

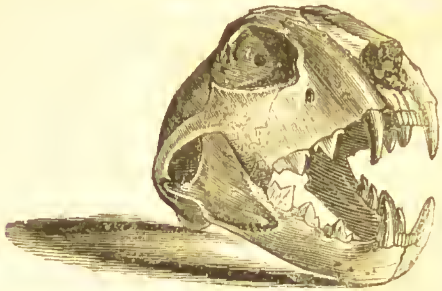
perform, they afford the most simple and striking illustration of the principles above enunciated.



TAB. 18.—SKULL OF THE BENGAL TIGER.

12. OSTEOLOGICAL CHARACTERS OF THE CARNIVORA.—If we examine the jaws of the skulls before us, those of a Bengal tiger, and of a cat, we perceive that there are cutting teeth in front,—sharp fangs on the sides,—and molar, bruising, or crushing teeth, in the back part. The molar rise into sharp lanciform points, and over-lap each other in the upper and lower jaw, like the edges of a pair of shears; and the teeth are externally covered with a thick crust of enamel. This is evidently an apparatus for tearing and cutting flesh, or for cracking bones; but is not suited for grinding the stalks or seeds of vegetables. The jaws fit together by a transverse process, which moves in a corresponding depression in the skull, like a hinge (Tab. 18); they open and shut like shears, but admit of no grinding motion; this, then, is such an articulation as is adapted for a carnivorous animal; and every part of this instrument is admirably fitted for its office.

But all these inimitable adjustments would be lost, were there not levers and museles to work the



Tab. 19.—Skull of a wild cat.
*(Felis Canadensis.)*

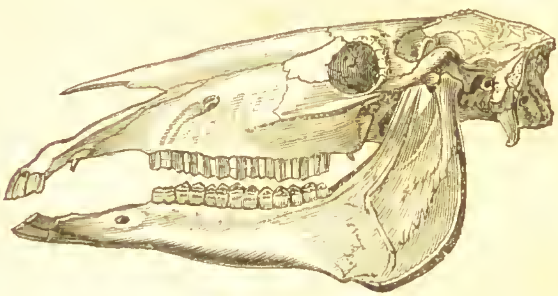
jaws,—were not eaeh portion of the animal frame adapted to all the other parts,—and were not the instinets and appetites of the animal sueh as are caleulated to give to this apparatus its appropriate movements. Let us reverse the order of the argument,—let us assume that the stomaeh of an animal be so organized as to be fitted for the digestion of flesh only, and that flesh reeent,—we should find that its jaws would be so eonstructed as to fit them for devouring live prey,—the elaws for seizing and tearing it,—the teeth for eutting and dividing it,—the whole system of its powers of motion for pursuing and overtaking it,—the organs of sense for discovering it at a distanee,—and the brain endowed with the instinet neeessary for teaehing the animal how to eoneeal itself, and lay snares for its victims.

Such are the general relations of the structure of carnivorous animals, and which every being of this class must indispensably combine in its constitution, or its race cannot exist. But subordinate to these principles, are others connected with the nature and habits of the prey upon which the animal is intended to subsist, and thence result modifications of the details in the forms which arise from the general conditions. Thus, in order that the animal may have the power requisite to carry off its prey, there must be a certain degree of vigour in the muscles which elevate the head; and thence results a determinate form in the vertebræ or bones from which these muscles originate, and in the back of the head in which they are inserted. That the paws may be able to seize their prey, there must be a certain degree of mobility in the toes, and of strength in the claws, and a corresponding form in all the bones and muscles of the foot. It is unnecessary to extend these remarks, for it will easily be seen that similar conclusions may be drawn with regard to all the other parts of the animal.* In the tiger and the cat we have a familiar illustration of what has been advanced.

13. STRUCTURE OF THE HERBIVORA. — In animals which are destined to live on vegetables we have the same mutual relations; the sharp fangs of the teeth are wanting, the enamel is not all placed

* Consult Cuvier's "Théorie de la Terre;" "Leçons d'Anatomie Comparative;" "Ossemens Fossiles;" &c.

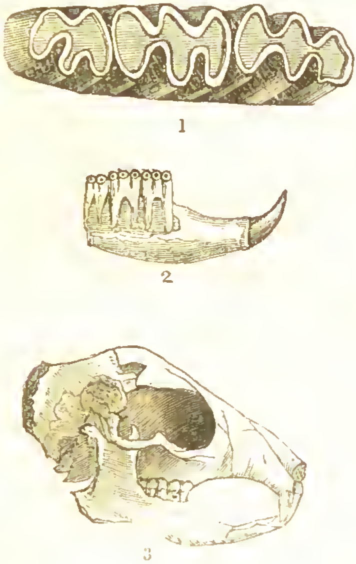
on the top of the teeth as in the carnivora, but arranged in deep vertical layers, alternating with bony matter; and this arrangement, in all states of the teeth, secures a rough grinding surface, as in the horse and the elephant. The flat molar teeth



Tab. 20.—Skull of the horse.

are not formed for cutting, but for mastication, and the jaws are loosely articulated together so as to allow of a grinding movement: had the socket and corresponding part of the jaw been the same as in the tiger, the tooth could not have performed its office. Again, I might proceed in the argument, and show the adaptation of the muscles of the head to the apparatus here described; and beginning with the jaw, review the whole animal frame, and demonstrate how all its parts are alike wonderfully constructed and fitted together, to perform the functions necessary for the being to which it belongs.

14. STRUCTURE OF THE RODENTIA, OR GNAWERS. — In the jaws of an intermediate order of animals, we find new modifications of the same



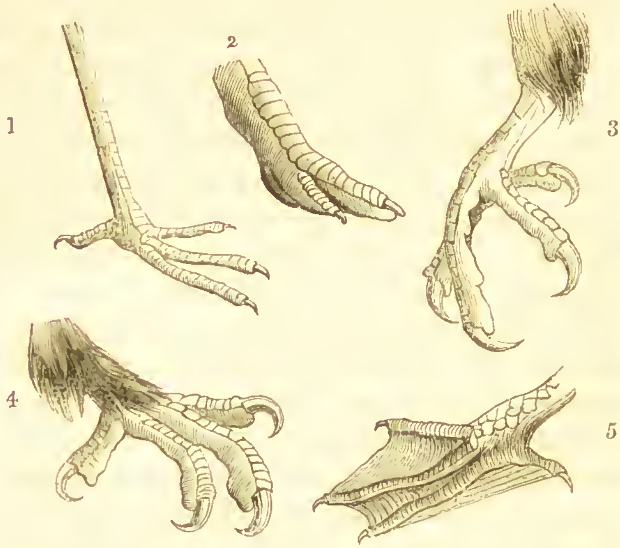
TAB. 21.—SKULL AND TEETH OF RODENTIA, OR GNAWERS.

Fig. 1. Molar teeth of the upper jaw of a Florida rat (*Arvicola Floridana*) magnified; seen obliquely. Fig. 2. Left side of the lower jaw, of the natural size. Fig. 3. Skull of the squirrel.

apparatus. Thus the *rodentia*, or gnawers, have long sharp cutting teeth, like nippers; it is by these that the rat can very speedily gnaw a hole through a board, and the squirrel in a nut, in consequence of their exquisite adaptation for these operations. In the skull of the squirrel (Tab. 21, fig. 3) the front teeth are of enormous size, as compared with the molar, and they lock together in such manner as to render a grinding movement impossible; a new adjustment has, therefore, been supplied,—the lower jaw is so adapted as to work in the skull neither in a transverse nor in a rotatory direction, but lengthwise, like the action of a carpenter using his plane, the teeth moving backwards and forwards, as may be observed in the rabbit while eating its food. The enamel of the molar teeth (see Tab. 21, fig. 1) is placed vertically and transverse to the jaw, so as to form an admirable grinding surface. But this is not the only variation of structure observable in the teeth of these animals. The incisors being implements of constant use, are renewed by continual growth, and there is a special provision for their support in a bent socket. The enamel is unequally distributed round the tooth, being very thin behind and thick in front, by which means the cutting edges are always preserved; for by the very act of gnawing, the hinder part of the incisor wears away quicker than the fore part, and thus a sharp inclined edge, like that of an adze or chisel, is maintained, and which is the very form required in the economy of the animal. The skull of the common rabbit or hare will exemplify these remarks.

15. General inferences.—These are but a few examples of those admirable adaptations of means to ends which are observable throughout

the various classes of organized beings: but the limits of a single lecture will not allow me to be more diffuse, and I trust it is unnecessary to offer further remarks, to show that the conclusions of geologists, as to the ancient inhabitants of our globe, are not vague assumptions, as those unacquainted with the science might suppose, but the legitimate deductions of laborious and patient investigations. A few teeth and bones—sometimes but a single relic of this kind—are the elements by which the comparative anatomist is enabled, not only to restore the forms of creatures now banished from the face of the earth, but also to ascertain their habits and economy, and even arrive at positive conclusions respecting the nature of the country of which they were once the inhabitants. If we find the remains of animals which lived on vegetables, it follows that there must have been vegetables for their subsistence, and a condition of nature calculated for the growth of vegetable productions; a soil fitted for their existence, and a country diversified by hills, valleys, and plains, with streams and rivers to carry off its superfluous waters. The same laws, under certain modifications, apply to other classes of beings. In birds, the form of the feet is modified according to the habits of the different orders. In the parrot, (Tab. 22, fig. 3,) the claws are adapted to climb trees and perch on the branches; but in the eagle they are widely different, for its talons are constructed to lacerate and tear its prey, (Fig. 4.) The feet of aquatic birds are formed like a paddle or oar, to




TAB. 22.—DIFFERENT FORMS OF FEET IN BIRDS.

Fig. 1. Foot of the heron; Fig. 2. Of the ostrich; Fig. 3. Of the parrot; Fig. 4. Of the eagle; Fig. 5. Of the pelican.

enable them to make their way through the water (Fig. 5); those of birds that frequent marshes have a great expansion, like a tripod, that they may move over the unstable surface of the morass (Fig. 1); while in species destined to inhabit sandy deserts, as the ostrich (Fig. 2), the feet present a corresponding change of structure.

We perceive, therefore, that every vertebrated animal has a solid and durable skeleton, or osseous support, formed upon one general plan, but modified in almost endless variety, in the relative magnitude, situation, and aspect of the different parts, so as to adapt itself to the various habits and functions of the diversified forms of animal life. In short, that the Author of nature has by these changes varied the same general fabric in innumerable ways; bestowed upon it a thousand different instincts and passions; adapted it to every element and climate; and to every possible variety of food and mode of existence.

From a knowledge of these principles of the correlation of the different parts of every organized being, which I have thus attempted to explain, we may understand how the scientific observer can reconstruct the entire animal fabric: and we are now prepared to enter upon that department of geology called *Palæontology*, or the science which relates to the fossil remains of the beings which inhabited our planet in former ages.

16. Fossil bones.—As the bones are the least perishable parts of the animal structure, they become the most frequent, and often the only indications of the zoological characters of the more ancient epochs. Occasionally very delicate parts, such as the tunic of the eye, the membranes of the stomach, and the wings of insects, are preserved in a fossil state, examples of which we shall hereafter adduce. In the older rocks, the bones are generally mineralized, and no longer possess the white and glossy

appearance of the recent skeleton; but those which occur in the superficial gravel, and in caverns, are commonly of a porous and earthy character, like bones that have lost a portion of their animal matter by being buried in a dry and loose soil.

The animals whose fossil remains I now proceed to describe, may be separated into two classes—the HERBIVORA, whose bones occur in the gravel and marl,—and the CARNIVORA, which are found in fissures and caverns.

17. FOSSIL ELEPHANTS, OR MAMMOTHS.*—I will first notice the fossil remains of the animals of the elephantine family, which occur in great abundance, and are very generally distributed. In the earlier ages, these colossal bones were supposed to belong to gigantic races of mankind, and hence the tradition of giants possessed by every country in Europe: nor need we smile at the ignorance and credulity of our ancestors, for, not many years since, a fossil tooth of an elephant, which was discovered in digging a well in Brighton, was supposed to be a petrified cauliflower!—In Russia, and more particularly in Siberia, the fossil bones of elephants are found throughout all the low lands, and in the sandy plains, but not in the elevated primary chain of hills, stretching from the borders of Europe to the nearest extreme point of America, and south and north from the base of the mountains of central Asia, to the shores of the Arctic sea.

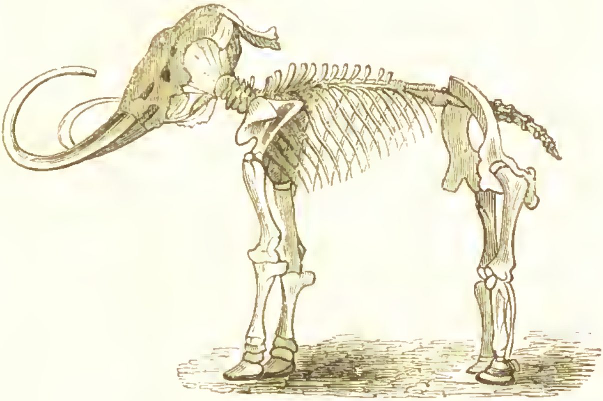
* From the Arabic *behemoth,* signifying *elephant.*

Within this space, which is almost equal in extent to the whole of Europe, fossil ivory is everywhere to be found; and the tusks are so numerous, and well preserved, especially in Northern Russia, that thousands are annually collected, and form a lucrative article of commerce. In Siberia alone, the remains of a greater number of elephants have been discovered, than are supposed to exist at the present time all over the world. In a low island in the Frozen Sea (72° north latitude) bones of mammoths are seen imbedded; and they also abound in an iceberg on the north-west angle of the American continent, near to Behring's Straits. The turquoises of Simone are composed of mammoths' bones impregnated with some metallic oxide.

18. Mammoth and rhinoceros imbedded in ice.—But the most remarkable fact relating to these remains, is the preservation, not merely of the bones, but of entire animals, with their flesh and skin, in ice-bergs and frozen gravel! In 1774, near Vilhoui, the carcase of a rhinoceros was taken from the frozen sand, where it must have been concealed for ages, the soil of that region being always frozen to within a few inches of the surface. The carcase was a complete natural mummy, part of the skin being still covered with long hairs, and forming a warmer covering than that of the African rhinoceros. The discovery of a mammoth, under similar circumstances, is yet more interesting. It appears, that towards the close of the last century,

a Tungusian fisherman observed in a cliff of ice and gravel, on the banks of the river Lena, a shapeless mass, the nature of which he was unable to determine. In the course of the next year it was more visible, and on the third a large tusk was seen projecting from the ice-cliff, and at length became detached. On the fifth year, an early thaw set in, and the entire carcase of a mammoth was exposed, and at length fell upon the ground. It was twelve feet high, and about sixteen feet in length; the tusks were nine feet long. The flesh was in such a state of preservation, that it was devoured as it lay by wolves and bears, and the hunters fed their dogs with the remains. The skin was covered with hair consisting of black bristles, thicker than horsehair, and fifteen inches in length; of wool of a reddish brown, and hair of a fawn colour; and with a mane on the neck. Upwards of 30lbs. of hair were collected; specimens of which may be seen in the Hunterian museum, of the College of Surgeons. The ear remained dry and shrivelled; the brain and even the capsule of the eye were preserved! the bones and part of the integuments, and a considerable quantity of the hair, are in the Museum of Natural History at St. Petersburgh. The accompanying sketch (Tab. 23) represents the skeleton in its present state.

The occurrence of large mammalia, in latitudes where but few forms of animal life can now possibly find the means of subsistence, is a fact of so much interest, that I must indulge in a few additional remarks. The existing elephants belong to two species, namely, the African, which occurs as far south as the Cape of Good Hope, and the Asiatic,



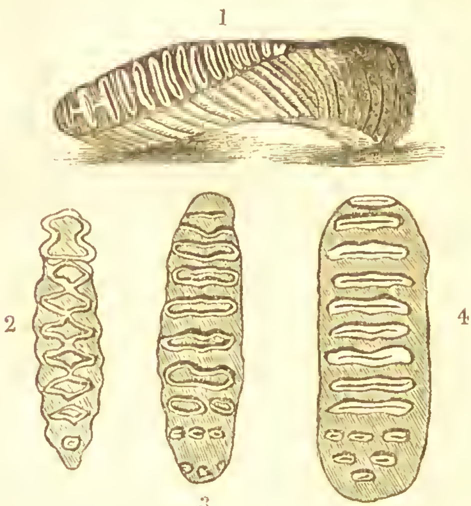
TAB. 23.—MAMMOTH FOUND IMBEDDED IN FROZEN GRAVEL IN SIBERIA.

(*Twelve feet high, and sixteen feet long.*)

which is limited to 31° north latitude. They are distinguished by certain characters; but those which more especially relate to our present inquiry, are the peculiarities of the teeth.

19. TEETH OF RECENT, AND FOSSIL ELEPHANTS. —The teeth of animals are formed of three distinct substances, which are variously disposed in different orders, according to the habits and economy of the species; a fact to which I alluded when treating of the anatomical character of those of the rodentia, &c. The nucleus of the tooth is composed of a bony matter, consisting almost entirely of phosphate of

lime, with albumen, and gluten; it is called ivory. This central portion of the tooth is covered by the enamel, a substance which is still more dense, and of a fibrous structure, and so hard as to strike fire with steel. In human teeth, the enamel covers the whole external surface, and the ivory forms the internal part. In herbivorous animals the enamel and ivory are intermixed; and there is in some genera, a third substance called *crusta petrosa*,




TAB. 24.—TEETH OF RECENT AND FOSSIL ELEPHANTS.

Fig. 1. Fossil tooth of an elephant from Brighton cliff, partially water-worn. Fig. 2. Crown of a tooth of the African elephant. Fig. 3. Grinding surface of a tooth of the mammoth, or fossil elephant. Fig. 4. Grinding surface of the Asiatic elephant.

which is a kind of yellowish, opaque ivory. These three substances enter into the composition of the teeth of the elephant, and their intermixture is apparent on the masticating surfaces; they are differently disposed in the two species. In the African elephant (Tab. 24, fig. 2,) the worn surface of the molar teeth presents a series of lozenge-shaped lines of enamel, having the ivory on the inner margin of the ridges, and being surrounded by the *crusta petrosa*. In the Asiatic species (fig. 4) the enamel forms narrow transverse bands; and the tooth of the mammoth, or fossil elephant, (figs. 1 and 3,) has an analogous, but somewhat different distribution. It is obvious that the structure here exhibited, is fitted for the grinding of vegetables; for the three substances, being of different degrees of hardness, produce by their unequal wearing, a constant rough surface for trituration.* The elephant has but four teeth in each jaw; the deficiency of prehensile teeth being supplied by that wonderful organ, the trunk. The teeth found in a fossil state, appear to be distinct from either of the recent species; but they are more nearly related to the Indian or Asiatic, than to the African, as you may observe by these specimens from Siberia, India, North America, and the cliffs on the Sussex coast. In some examples the teeth are water-worn, but most commonly very perfect, and exhibit but few marks of attrition. From a careful review of the characters of the fossil elephant, or mammoth of Siberia,

* See Dr. Roget's Bridgwater Treatise, for a lucid and interesting Essay on the teeth of various animals.

Cuvier determined that the species was now extinct; that the structure of the teeth, configuration of the skull, and the hairy and woolly skin, proved that it was adapted to live in a colder climate than that in which the Asiatic species could exist; and he inferred that the animals originally inhabited the countries where their remains are now found imbedded; and that the preservation of the carcases in ice, showed that the change in the temperature of the climate was sudden, and has since remained unaltered.

Mr. Lyell offers an ingenious solution of this difficult problem. He supposes that a large region of central Asia, perhaps the southern half of Siberia, may have enjoyed a climate mild enough to have admitted of the existence of the extinct elephants, for vegetation may be found in lat. 40° and 50° north; and from the physical geography of the country, that the whole tract from the mountains to the sea may have been upraised like Sweden, and the refrigeration of the north-east of Asia, and its present physical condition, have been the result.

My limits will not permit me to dwell at length on other discoveries of fossil elephants, but I will notice a few instances in our own country. On the coasts of Norfolk and Suffolk, so many teeth of elephants have been collected, that the late Mr. Woodward (author of "The Geology of Norfolk") calculated that they must have belonged to above

500 individuals. At Walton, in Essex, and at Herne Bay, bones and tusks have also been found. But by far the most extraordinary collection of the remains of British fossil elephants that I ever beheld, is in the possession of Mr. Gibson, of Bow, near London; it comprises skulls, tusks, and teeth, from the sucking animal to the adult, in a remarkable state of preservation; the whole of which were discovered in Essex. In the highly interesting museum of W. D. Saull, Esq. of London, many fine elephantine remains are also preserved. On the western coast of Sussex, and in the neighbourhood of Arundel, Patcham, and Brighton, teeth and bones of elephants have at different times been exhumed. At Brighton the teeth are found in a deposit of water-worn materials, consisting of loam, chalk, and broken flints, resting on a bed of shingle covering the chalk.* In the conglomerate, of which I have already spoken, (Tab. 15, p. 101,) as well as in the superincumbent deposit, the teeth of elephants, with bones and teeth of a species of deer, horse, and whale, occur, and are associated with marine shells. When these remains were imbedded, this part of the English coast must have joined the opposite shores of France, and have formed the boundary of a bay or estuary, of a country inhabited by large mammalia; for similar fossils are found in a deposit of a like character, along the French coast.

* See Geology of the South-East of England, p. 32.

20. THE MASTODON.—In various parts of North America, there are marshy tracts abounding in salt or brackish waters, which are frequented by deer, and other animals; a circumstance from which they have acquired the American name of *Lick*. In these morasses vast quantities of bones of gigantic terrestrial animals have been discovered. The spot most celebrated for these remains in Kentucky, is called Big-bone Lick, and is situated to the south-east of the Ohio, in the midst of a group of low hills, and is traversed by a small stream of brackish water. The bottom consists of a black

TAB. 25.—TOOTH OF THE GREAT MASTODON, FROM THE BANKS OF THE HUDSON; WEIGHT 4lbs.*
(*From Professor Silliman of Yale College.*)

fetid mud, intermingled with sand, and vegetable matter; and in this bog, bones of great magnitude

* The drawing is one-third of the diameter of the original.

occur in profusion. Some of them are referable to the fossil elephant, but others, as you may observe from the specimens before us, must have belonged to a creature not less gigantic, but with very different characters.

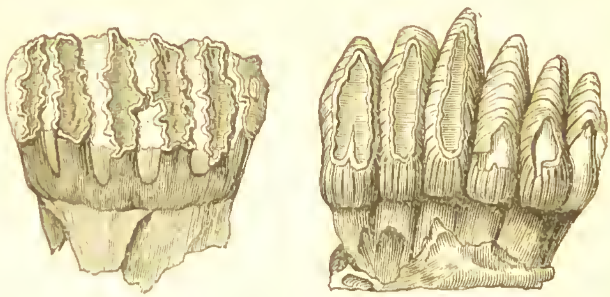
These teeth are composed of ivory and enamel only, and the enamel, which is very thick, is spread over the crown of the tooth, which, when unworn, is divided into several transverse tubercles, or processes, each of which is subdivided into two obtuse points; from this character of the teeth the name of MASTODON (from two Greek words, signifying mammillary teeth,) has been given to the animal to whom they belonged. These teeth have no relation to those of the carnivora; for although they have an external investment of enamel like those of the tiger, yet they are destitute of the longitudinal, serrated, cutting edge; and in those which are worn, the protuberances become truncated into a lozenge form. The structure is similar to that of the hog and the hippopotamus, and is fitted for the bruising and mastication of crude vegetables, roots, and aquatic plants. The bones and teeth of the mastodon have been found throughout the plains of North America, from north of Lake Erie to as far south as Charleston, in South Carolina; they have been also discovered on the Continent, and in the Crag of Norfolk, in England. Here are examples from the banks of the Ohio, of the Hudson, and from

Big-bone Lick, presented to me by Professor Silliman: this is an example of a young perfect tooth; and this of a very old animal, for the grinding surface is almost worn flat by use. These remains are found at moderate depths, with no marks of detrition; it is therefore evident that the animals must have lived and died in the country where their relics are entombed. The skeletons of the great mastodon found in the bogs of Louisiana are in a vertical position, as if they had sunk in the mire; and one discovered in New Jersey, forty miles to the south of New York, was bedded in black earth, in the same position, the head being on a level with the surface of the soil. There is an entire skeleton of the mastodon in the museum of Mr. Peale, in Philadelphia, which is fifteen feet long and eleven feet high; and by this specimen it has been ascertained that the great mastodon, or animal of the Ohio, as it has been called, was not unlike the elephant, but somewhat longer and thicker. It had a trunk or proboscis, tusks, and four molar teeth in each jaw, and no incisors. From the nature of its food, as shown by the structure of the teeth, it must have frequented marshy tracts, but it was undoubtedly a terrestrial animal. In the midst of a collection of these bones imbedded in mud, a mass of small branches, grass, and leaves, in a half bruised state, was discovered, and a species of reed, common in Virginia; the whole appeared to have been enveloped in a sack, probably the stomach of the animal. In another instance, traecs of the trunk or proboscis were observed. The tusks are eomposed of ivory, and vary in their curvature. The bones of this colossal quadruped are found remarkably fresh and well preserved; they are generally impregnated with iron, and have evidently been buried in the earth for ages. No living instance of this creature is on record, and no doubt ean exist that its raee has long been extinct. The Indians believe that men of similar proportions were coeval with the mastodon, and that the Great Spirit destroyed both with his thunder.* There are several species, some of which have been found in North America only, and others in Europe. That eminent philosopher Baron Humboldt discovered a tooth of the mastodon near the volcano of Imbaburra, at an elevation of 1,200 fathoms. A very fine skull, with teeth, of the great mastodon, from Big-bone Lick, has lately been placed in the British Museum, and is well worthy your notice when visiting that magnificent collection. This specimen, which was purchased for 150 guineas, consists of the cranium with two perfect grinders, and the sockets of the other two. The length of the skull, from the occiput to the soekets for the tusks, is 36 inches.

21. Mastodons found in the Burmese empire.—I now request your attention to the remains

* Cuvier. See an admirable English Epitome of Cuvier's Fossil Animals, by Edward Pidgeon, Esq. 1 vol. 8vo. 1833.

of a species of mastodon which, from the structure of the teeth, fills up, as it were, the interval that separates the mastodon from the elephant; it



1 2

TAB. 26.—FOSSIL TEETH OF THE ELEPHANT AND MASTODON.

(*One-sixth the diameter of the originals.*)

Fig. 1. Tooth of the fossil Elephant from Big-bone-lick. Fig. 2. Tooth of the Mastodon elephantoides from near Ava.

has been named by Mr. Clift, the *Mastodon elephantoides*,* (Tab. 26, fig. 2). The teeth, which, together with the fossil bones and wood before us, I owe to the liberality of Mr. Craufurd, present characters very peculiar; for while their structure is similar to that of the great mastodon, the ridges in which the crown of the teeth is disposed, resemble those of the elephant; and the worn surface of the teeth would bear an analogy with that of the grinders of the African elephant. These teeth, together with bones and teeth of the

* Geological Transactions, vol. ii. new series.

hippopotamus, rhinoceros, horse, tapir, ox, antelope, hog, gavial, fresh-water turtle, &c. and silicified wood, are part of an extensive collection formed about ten years since by Mr. Craufurd, on his mission to Ava. In descending the river Irawaddi, his steam-boat, owing to the shallowness of the water, ran aground, between Prome and Ava, about 20° north latitude, near some petroleum wells, where the bank of the river presents a cliff 80 feet high; and on the strand were observed masses of petrified wood, and vast quantities of bones. The adjacent country is formed of low, sterile sand-hills, intersected by ravines, with beds of gravel, which are here and there cemented into a conglomerate by iron and carbonate of lime, by the process which was explained in the former lecture (p. 64). Scattered over the surface, in some instances lying loose in the sand, and in others half buried, were masses of silicified wood, and fragments of bones, which had become exposed, from the removal of the sand by the winds and rains. The bones, as you may perceive in these incrusted specimens, were more or less invested with a hard crust, which appears to be a mere local concretion, from the consolidation of loose sand by ferruginous and calcareous infiltrations. The natives who assisted Mr. Craufurd's party in collecting these remains, believed that they were the bones of giants who had warred against Vishnu, by whom they had been destroyed. On these interesting discoveries, Dr.

Buckland* calls attention to the remarkable fact, that in the twelve chests full of osseous remains, not a fragment belongs to the elephant, tiger, or hyena, which abound in India; while evidence is afforded that the extinct mastodon must once have swarmed in the districts bordering on the Irawaddi.

22. The sivatherium.†—The flanks of a range of hills belonging to the Sub-Himalaya mountains, between the river Sutlej and the Ganges, are covered by beds of concretionary sandstone, conglomerate, and loam, bearing a close analogy to those of Ava. These hills, which are called the Sivalik, (from Siva, an Indian deity,) rise to an altitude of from one to three thousand feet above the level of the sea. In these deposits occur immense quantities of fossil teeth and bones of the elephant, mastodon, hippopotamus, rhinoceros, elk, ox, horse, deer; and of several carnivorous animals, crocodiles, gavials, and fresh-water turtles; with fluviatile shells, and remains of fishes; an extinct species of *monkey*, and of the *camel* have also been found. These interesting discoveries were made by Captain Proby Cautley, of the Bengal artillery, and Dr. Falconer, who, with an energy and perseverance beyond all praise, have followed out their researches, and transmitted magnificent collections of these remains to England. The valuable specimens in my

* See a Memoir on the Bones from Ava, by Dr. Buckland. Geol. Trans. vol. ii. New Series.

† From *Siva*, an Indian deity, and *therion*, wild animal.

museum were, with great liberality, sent to me by Captain Cautley; among them you may observe bones and teeth of the same species of mastodon as that which has been found at Ava; with bones of the horse, rhinoceros, hippopotamus, gavial, and a fine skull of the fossil elephant, with four teeth perfect and in place. But the labours of these naturalists have been yet more richly rewarded by the discovery of the skull, and other parts of the skeleton, of a creature hitherto unknown; one that forms, as it were, a link between the ruminants and the large pachydermata. From the skull, which is remarkably well preserved, it is ascertained that the animal had four horns, and was furnished with a proboscis; that it was larger than a rhinoceros, and combined the horns of a ruminant, with the characters of the pachydermata; the discoverers have named it *Sivatherium*. This animal, when living, must have resembled an immense antelope, or gnu; with a short and thick head, an elevated cranium, crested with two pairs of horns; the front pair were small, and the hinder large, and set quite behind, as in the aurochs. With the face and figure of the rhinoceros, it must have had small lateral eyes, great lips, and a nasal proboscis; these inferences have been deduced from certain anatomical characters exhibited by the fossil bones, but upon which I cannot enlarge.

23. The megatherium. (*Mega*, great, and *therion*, wild beast.)—The Pampas, those immense

plains of South America, on the south bank of the river Saladillo, which present a sea of waving grass for 900 miles, are principally composed of alluvial loam and sand, containing fresh-water with marine shells, and were once, like Lewes Levels, a gulf, or arm of the sea. In these alluvial deposits, enormous bones have been frequently discovered. Towards the close of the last century, an almost entire skeleton of a gigantic animal was dug up, at the depth of 100 feet, in a bed of clay, on the banks of the river Luxor, about four leagues W.S.W. of Buenos Ayres. This skeleton was sent, in 1789, to the museum at Madrid, where it now remains. It is described and figured by Cuvier, under the name of the *megatherium*. In 1832, Sir Woodbine Parish, with considerable labour and expense, collected many parts of the skeleton of a similar creature from the Salado; and actually diverted for a time the river from its course, that he might disinter these precious relics, which he has since deposited in the Hunterian Museum of the Royal College of Surgeons. But, before I enter upon a description of these fossils, it will be requisite to notice the remains of an animal of analogous structure, which has been discovered in the saltpetre caves of Virginia and Kentucky, and which, from the size of the ungueal or claw-bones, has been named the *megalonyx*.

24. THE MEGALONYX.*—I have placed upon the

* *Mega*, great; *onyx*, claw. See a "Description of the Fossil Bones of the Megalonyx," in Dr. Harlan's Medical and Physical Researches.

table, models of all the bones which are now preserved in the museum of Philadelphia, for which I am indebted to an eminent physician and geologist of that city, Dr. S. G. Morton, the author of the most valuable treatise that has appeared on the fossils of the United States.* The late American President, Jefferson, who first described these remains, inferred, from the form and magnitude of the claw-bone, that the original was a carnivorous animal of colossal proportions. But Cuvier, by his profound knowledge of the principles of anatomy, determined, from certain characters of the articulating surfaces,† that the animal was related to the *bradypus*, or sloth. I will endeavour briefly to explain to you the mode by which this induction was obtained. The paws or feet, both of the canine and feline tribes, are armed with claws; in the former, the nails are thick and coarse as in the dog, wolf, &c. and fitted to bear the friction and pressure incident to a long chase; while in the cat tribe, on the contrary, they are curved and sharp, which qualities are preserved by a peculiar mechanism. The last bone which supports the claw is placed laterally to the penultimate bone, and is so joined to it that an elastic ligament draws it back, and raises the sharp extremity of the claw upwards;

* Synopsis of the Fossils of the Cretaceous Group of the United States, by S. G. Morton, M.D. &c.

† That surface of the bone which forms a joint with another bone.

and the nearer extremity of the farthest bone presses the ground in the ordinary running of the animal, while the claw is retracted into a sheath: but when the creature makes a spring and strikes, the claws are uncased by the action of the flexors or bending tendons. In the Bengal tiger, the claws are so sharp and strong, and the arms so powerful, that they have been known to fracture the skull of a man, by a single touch in the act of leaping over him.* A cat affords a familiar illustration of this peculiarity of structure; when pleased, its claws are retracted, and when angry they are thrown out. In the claw of the megalonyx there is no such lateral provision for its retraction, and the point could not have been raised vertically, as in the cat, so as to have permitted it to touch the ground without injury. The articulating surface is double, that is, there is a ridge or spine in the middle, and it must, therefore, have moved like a hinge.

25. THE SLOTH.—There is among recent animals an order called *tardigrada*, from their feeble power of progression—these are the *paresseux*, or sloths; which have long toes, and large nails, of a construction similar to those of the fossil. Their nails are folded up, but in a very different manner from those of the cat; they only enable the animal to walk, in the same way as if our fingers were folded under the palms of the hands. This is a

* Sir C. Bell.

specimen of the *bradypus* (slow-footed) *tridactylus*, (three-toed) from South America, and which is also called the *ai*, from its peculiar cry. The arms are double the length of the legs, and, from the construction of the limbs, the animal, when it walks, or rather crawls on the ground, is obliged to drag itself along on its elbows. But these creatures are destined to inhabit trees; their proper element is on the branches, and they can pass from bough to bough, and from tree to tree, with a rapidity which soon enables them to lose themselves in the depths of the forests. They live on the leaves and the young shoots, and unless disturbed, never quit a tree till they have stripped off every leaf. To avoid the labour of a descent, they drop to the ground, previously coiling themselves into a round ball, in which state, while attached to the branch, they may be taken alive. Thus the habits and economy of the sloth point out the necessity for a peculiarity of structure in its nails. The monkey leaps and swings himself from tree to tree, and catches at will the branches or the trunk; but the sloths do not grasp; their claws are mere hooks to hang by, and their great strength is in their arms. They never unfix one set of hooks until they have caught a secure hold with the other, thus hanging by their arms and legs, while their bodies are pendant; and they sleep in the same position. In the bones of the arm of the *megalonyx*, we find a close analogy with those of the sloths. The humerus, or arm-bone, has a long internal condyle for the origin of very large muscles to move the enormous claws; and there is a foramen or opening for the passage of nerves and blood-vessels, to protect them from the pressure to which they would be exposed from the powerful muscular action; while the radius is so constructed as to allow of a rotatory motion of the arm. With the bones of this animal were found masses of osseous polygonal scales, like mosaic work; and it is supposed that the original was covered with an armour resembling that of the armadillo.

I now proceed to the consideration of the megatherium. This creature was about seven feet high, and nine feet long, and therefore larger than the largest rhinoceros; but this comparison by no means conveys a proper idea of its bulk, since its proportions are perfectly colossal, the thigh-bone being three times as large as that of the elephant, and the pelvis or haunch-bone, twice the breadth. It possessed no incisor teeth, and the molars or grinders are seven inches long, of a prismatic form, and, like those of the elephant, composed of ivory, enamel, and *crusta petrosa*, or cement. They are so formed, that the crown of the teeth always presents two cutting, wedge-shaped, salient angles. As in an adze a plate of steel is placed between two of iron so as to project in a line, in like manner these teeth have in the centre, a cylinder of ivory, which is protected by a plate of enamel, and has an external coating of *crusta petrosa;* these teeth are, therefore, admirably adapted for cutting and bruising vegetable matter. The entire fore-foot is about a yard in length, and the claws are set obliquely to the ground, like those of the mole; a position which would render them digging instruments of great power. The pelvis measures five feet in width, and the sacral aperture of the spinal marrow is one foot in circumference! This enormous size was suitable to the habits of an animal requiring to maintain an upright posture for a considerable time, and to employ its fore-feet in digging. As Dr. Buckland has fully elucidated the structure and habits of this enormous being of the ancient world, and his work is, or ought to be, in every library, I will not dwell on other important peculiarities in its osteology, but content myself with stating, that the *megalonyx* and *megatherium* were intermediate between the sloths, armadillos, and ant-eaters. The megatherium, with the head and shoulders of the sloth, combined in its legs and feet an admixture of the characters of the armadillo and ant-eater. Both the megalonyx and megatherium were herbivorous, but they were not capable of climbing, even had there been trees that could have supported their enormous weight: their food, like that of the armadillos, must have consisted of roots and stems of succulent vegetables, which the peculiar structure of their feet enabled them to dig up with facility. Like their recent types, they are limited in their geographical distribution to nearly the same regions of the new world.*

The skeleton of another colossal quadruped has very recently been discovered near Buenos Ayres, and will shortly be placed in the Hunterian Museum, through the liberality of Sir Woodbine Parish. The original was of the size of an ox, and covered, like the armadillo, by an armour, formed of polygonal scales. From the fluted structure of the teeth, this animal has been named *glyptodon*, by Professor Owen.

26. FOSSIL HIPPOPOTAMUS, RHINOCEROS, HORSE, &c.—With the fossil remains of the mammoth, elephant, and other large mammalia, the teeth and bones of several species of hippopotamus, horse, elk, ox, and auroch, are very commonly associated. In the Vale of Arno, in Italy, immense quantities of the teeth and bones of hippopotami are found. On the table before us are specimens from that locality; as well as molars and incisors of a young animal from Huntingdonshire, presented by Mr. Saull; and tusks, teeth, and bones, dug up in alluvial marl, at Southbourn, in Sussex. Bones of this animal also occur in alluvial deposits near Rome; and here are examples, collected by the Marquis of Northampton. Among the objects sent me by Captain Cautley, from India, are several fine portions of jaws, with teeth, belonging to a hippopotamus (*H. Sivaliensis.*) Several extinct species of hippopotamus have been

* See Dr. Buckland's Bridgewater Essay.

determined by Baron Cuvier, one of which was not more than half the size of the common species. The bones and teeth of the rhinoceros are constantly associated with those of the fossil elephant; and in this country they occur in superficial gravel and loam: these examples of teeth were discovered in a bed of gravel, on Petteridge common, in Surrey. But the most extraordinary and interesting fact, relating to the fossil rhinoceros, is the discovery of the entire carcass, with the skin, in frozen sand, on the banks of the Wilaji, in Siberia. The head was extremely large, and sustained two very long horns; it had no incisors; the body was covered with brown hair, particularly on the limbs; and the general form of the animal was lower and more compact than the living species.

The teeth and bones of one or more species of horse, occur very constantly with those of the large extinct pachydermata; in these examples of the conglomerated shingle from Brighton cliffs, the coffin, pastern, and cannon bones, as they are termed, are imbedded; in some instances the cavities of the long bones are filled with crystallized carbonate of lime.

In addition to the animals we have already noticed, the deposits now under examination contain many lost species of ruminants, and of other orders of mammalia. The fossil remains of an animal resembling the musk-ox were found with elephants' bones in Siberia; an extinct species of fallow-deer in Scania; of roe-buck and reindeer in France; and of gigantic oxen, aurochs,* deer, &c. in our own country. It is worthy of remark, that the fossil pachydermata, such as the elephant, rhinoceros, &c. belong to genera which inhabit torrid climes, while the ruminants are of those which at the present time are natives of northern latitudes.

TAB. 27.—THE DINOTHERIUM.

27. THE DINOTHERIUM.†—I shall conclude my remarks on the large mammalia with the description of a gigantic creature of a very peculiar character, whose bones occur with those of the mastodon, elephant, and other animals which we have already

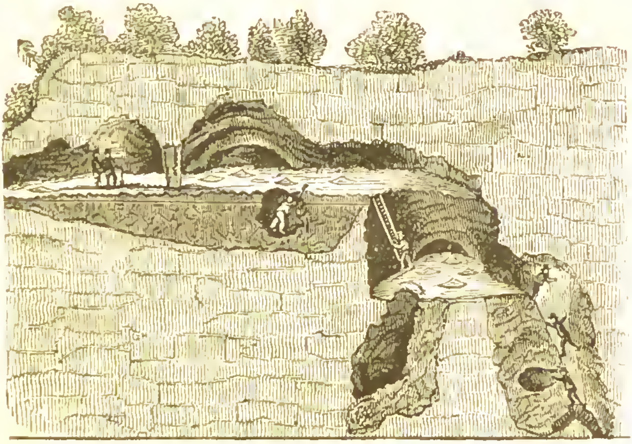
* The auroch is a species of wild bull or buffalo, distinct from the common ox. The horns of the fossil ox are sometimes of enormous size: Mr. Parkinson had a pair in which the length of each horn was 2 feet 7 inches.

† *Dinos*, terrible; *therion*, a wild beast.

examined, as well as with the remains found in more ancient deposits. In various parts of the south of France large molar teeth, resembling in their form and structure the teeth of tapirs, have occasionally been found; they are described by Cuvier under the name of the "Gigantic Tapir." Models of the principal specimens deposited in the Museum at Paris, have been presented to me by Baron Cuvier, together with others which I shall place before you on a future occasion. Subsequent discoveries in Bavaria, Austria, and particularly at Eppelsheim, about twelve leagues south of Mayence, have made us acquainted with the form and structure of the original, which appears to have been one of the largest of lacustrine animals, the skeletons showing that some individuals were eighteen feet in length! The scapula, or shoulder-blade, was like that of the mole, and the fore leg must therefore have been adapted for digging up the earth. The most extraordinary deviation from ordinary types consists, however, in the curved tusks, which are fixed in the lower jaw in a downward direction, as those of the walrus are in the upper; the lower jaw is four feet in length. From the structure of the anterior portion of the cranium, and the disposition of the nasal fossæ, it is certain that the creature had a proboscis; besides, it possesses no incisor teeth with which to seize its food, and the jaws do not even close together in front. The tusks were probably weapons of defence, like those of the elephant. This drawing, (Tab. 27,) from a restoration by M. Kaup, an eminent German naturalist, represents the supposed form of the original ereature. It would appear that the dinotherium was nearly related to the hippopotamus, forming a link between the eetaeea and paehydermata, or large terrestrial mammalia; and that it was an herbivorous aquatie animal, inhabiting lakes and marshes.

28. Fossil carnivora in caverns. — We have passed in review the extinet population of a remote period of our globe,—those enormous paehydermata, the mastodons and mammoths, that lie buried in the alluvial and superfieial strata. We now arrive at the eonsideration of phenomena not less interesting—the oeeurrenee of immense numbers of skeletons of earnivorous animals in fissures and eaverns. In the former diseourse I alluded to the eavities whieh abound in eertain roeks of limestone, and deseribed the proeess by whieh their roofs, floors, and walls were eoated with sparry inerustations, and ornamented with stalaetites and stalagmites (p. 62). Some of these eaverns appear to have been oeeasioned by the destruetion of the softer portions of the roek by subterranean streams; others are so extensive, and present sueh deeided marks of angular fraeture, as to leave no doubt that they have been produeed by the shoeks of earthquakes. The oeeasional oeeurrenee of the bones of animals in sueh eavities might reasonably be

expected. Those that admitted of easy access from without, might be frequented by species whose habits lead them to retire into dark and secret recesses; while others, as kids, deer, &c. might fall into open fissures, and their bones thus become enveloped and preserved in calcareous incrustations. But the immense quantities of only one or two species of carnivora that are found in some caverns, show that these have been for a long period the dens of extinct species of bears, wolves, tigers, hyenas, and other carnivorous tribes.



TAB. 28.—VERTICAL SECTION OF THE CAVE OF GAYLENREUTH.

29. CAVE OF GAYLENREUTH.—For many centuries, certain caverns in Germany have been celebrated for their osseous treasures, particularly those

in Franconia: the most remarkable is that of Gaylenreuth, which lies to the north-west of the village, on the left bank of the river Wiesent. The entrance, which is about seven feet high, is in the face of a perpendicular rock, and leads to a series of chambers from fifteen to twenty feet high, and several hundred feet in extent, terminated by a deep chasm, which, however, has not escaped the ravages of visitors. This cavern is perfectly dark, and the icicles, or pillars of stalactite, reflected by the torches which it is necessary to use, present a highly picturesque and striking effect. The floor is literally paved with bones and fossil teeth; and the pillars and corbels of stalactite also contain osseous remains. Loose animal earth abounding in bones, forms in some parts a layer ten feet in thickness. A graphic description of this cave was published by M. Esper, more than sixty years ago; at that period, some of the innermost recesses contained waggon loads of bones and teeth; some imbedded in the rock, and others in the loose earth. The bones in general are scattered and broken, but not rolled; they are lighter and less solid than recent bones, and are often incrusted with stalactite. Through the kindness of Lord Cole, and Sir Philip de M. Grey Egerton, I am able to illustrate these remarks by an extensive suite of osseous remains, exhumed from the deepest recess in the cavern, and collected a short time since by these distinguished geologists. But the most interesting specimen in my possession is a remarkably perfect skull of a bear, which belonged to my late friend Mr. Parkinson, the author of that delightful work, "The Organic Remains of a Former World." A comparison of this relic with the skull of the polar bear, shows that it must have belonged to a species of *ursus*.* Cuvier, who enjoyed the opportunity of examining a very large collection of bones from Gaylenreuth, was enabled to determine that at least three-fourths of the osseous contents of the caverns belonged to some species of bear; and the remaining portion to hyenas, tigers, wolves, foxes, gluttons, weasels, and other small carnivora. By the bones which were referable to the bear, he established three extinct species of that genus; the largest of these has a more prominent forehead than any living species, and is called the *Ursus spelæus*, or bear of the caverns, and it is to this species the skull I have just mentioned belongs; the other has a flatter forehead, and has been named *Ursus arctoidæus*. The hyena was allied to the spotted hyena of the Cape, but differed in the form of its teeth and head. Bones of the elephant and rhinoceros are also said to have been discovered, together with those of existing animals,

* Their Royal Highnesses the Princes George of Cumberland and Cambridge, when inspecting my collection a few years since, at Lewes, pointed out this skull to me as resembling some fossils that had been exhumed from a fissure in limestone, in the kingdom of Hanover.

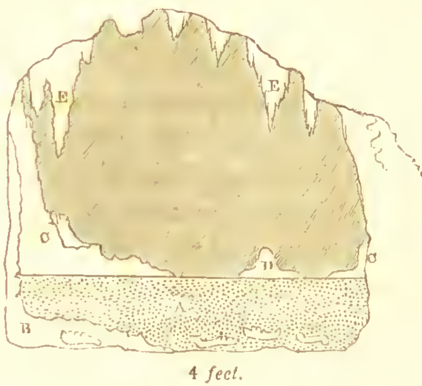
and fragments of sepulchral urns of high antiquity.

30. Forster's Höhle.—Another cavern in this part of Germany is mentioned by Dr. Buckland, as one of the most remarkable for the beauty of its incrustations. It is called *Forster's Höhle,* and varies in height from ten to thirty feet; its greatest width is about ten yards. In the side vaults or recesses, which descend, at an angle of about forty-five degrees, into the main chamber, the stalagmite has formed the appearance of cascades of pure alabaster, the waves of which seem to be rushing out at the bottom, to pour themselves into the stagnant lake of the same substance which covers the floor. The rocky roof has been corroded into deep cavities, which are separated by partitions of every conceivable form and tenuity, giving it the appearance of the richly fretted gothic roof of a chapel, with pendent corbels. Beautiful stalactites depending from these projections, reach almost to the floor, and contribute by their delicacy and transparency to throw additional richness over the scene.

It is certainly, as M. Cuvier remarks, a most extraordinary fact, that caves, spread over an extent of two hundred leagues, should have the same osseous contents. The relative proportions of the different species are computed to be as follow:—three-fourths belong to bears—two-thirds of the remainder to hyenas—and a small number to the tiger or lion, and to the wolf or dog; rolled pebbles of a greyish blue marble are the only extraneous materials found with the bones. Let me here call your attention to the singular association of species which some of these caves present; their recent types being widely separated. Thus in one cavern, animals allied to the spotted hyena of the Cape of Good Hope, are collocated with the remains of others related to the glutton, which inhabits Lapland; and in another, bones of the rhinoceros are associated with those of the reindeer. Numerous caves containing osseous remains are scattered over the continents of Europe and America; and even in Australia, fossil bones belonging to animals of different genera, but in a similar state of preservation, are found in caverns.

31. Bone caverns in England—Kirkdale cave.—In England caverns containing bones of bears, and other carnivora, in every respect analogous to those of Germany which we have just described, have been discovered and explored. Dr. Buckland, in his valuable work, the *Reliquiæ Diluvianæ*, has noticed several of the most important assemblages of this kind. The cave of Kirkdale, now so well known in consequence of the highly interesting disquisition on its contents by my distinguished friend, is one of the most celebrated. In the summer of 1821, a cave was discovered near Kirkdale, about twenty-five miles NN.E. of York, in a bank about sixty feet above the level of a small valley, and near a public road. Some workmen

who were quarrying stone, cut across the narrow mouth of a chasm, which had been choked up with rubbish, and overgrown with grass and bushes; and which from this cause, as well as from its inaccessible situation, had hitherto escaped observation, the entrance being so small that it was only possible for a person to enter in a bent position.




TAB. 29.—SECTION OF THE ENTRANCE OF THE CAVE OF KIRKDALE.*

A. Mud covering the floor of the cave to the depth of one foot, and concealing the bones.

B. Stalagmite incrusting some of the bones, and formed before the mud was introduced.

C. C. Stalagmite formed over the mud.

D. Insulated stalagmite on the surface of the mud.

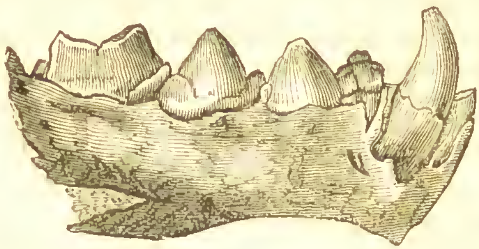
E. E. Stalactites dependent from the roof.

The passage is exceedingly irregular in its dimensions, varying from two to seven feet in breadth, and from two to fourteen feet in height; its greatest length is 245 feet. It divides into several smaller

* From Dr. Buckland's Reliq. Diluv.

passages, which have not yet been explored, as they are nearly closed by stalactital concretions; these cavities occur where the roof is intersected by fissures, which are continued for a few feet, but are gradually lost in the superincumbent limestone, and are thickly lined with stalactites. The true floor was only seen near the entrance, for in the interior the whole was covered with a bed of hardened mud or clay, about a foot in average thickness. The surface was perfectly smooth and level when the cave was first opened, except where stalagmites had formed upon it by infiltration from the roof. Where stalactitic matter incrusted the sides, it also extended over the bottom like a thin coat of ice; and therefore must have been formed since the mud was introduced. This mud or clay was filled with fragments of bones belonging to a great variety of animals; and some of the bones exhibited marks of having been gnawed. From many corroborative circumstances these appearances are, with much probability, supposed to have been occasioned by hyenas. The bones thus preyed upon belong to the tiger, bear, wolf, fox, weasel, elephant, rhinoceros, hippopotamus, horse, ox, and deer. Bones of a species of hare or rabbit, water-rat, and mouse, with fragments of the skeletons of ravens, pigeons, larks, and ducks, were also imbedded with these remains.

From these facts it is inferred that the cave was inhabited by hyenas for a considerable period, that many of the remains found there were of species which had been carried in, and devoured by those animals, and that in some instances the



Tab. 30.—The left side of the lower jaw of a hyena, from Kirkdale cave.

hyenas preyed upon each other. Portions of elephants' bones seem to show that occasionally the large mammalia also served as food; but it is probable that many of the smaller animals were drifted in by currents, or fell into the chasm, through fissures now closed up by stalactitical incrustations.

Kent's Cave, near Torquay, which is nearly 600 feet in length, has yielded immense quantities of bones of carnivora; and in the Isle of Portland, at Plymouth, and in the Mendip Hills, similar accumulations have been found. In the south-east of England but one instance is known; a fissure in the sand-rock at Boughton Quarries, near Maidstone, contained the jaw and bones of a hyena, which are now in the museum at Oxford. This fact proves the existence of the same condition of animated nature in this part of our island, as in the districts previously mentioned. Very recently a cave has been discovered near Plymouth, in which bones of hyenas were found in abundance, associated with those of the elephant, rhinoceros, horse, &c.

From what has been stated, we learn that our wastes and forests were once inhabited by extinct carnivora, belonging to genera whose recent species are almost entirely restricted to southern climates;—that these lived and died for successive generations, and were the prey or the destroyers of each other;—that the hyenas, according to their peculiar habits, dragged into their dens the creatures which they killed or found dead, and devoured them at their leisure;—that subsequently the races were annihilated, and were succeeded by animals of a character altogether different.

32. Diseased bones of carnivora found in caves.—Among the bones found in the caves of Germany are many in a condition which must have resulted from accident or disease. In some there has been a formation of new bony matter to repair fractures; in others there is anchylosis, or adhesion of the joints from inflammation: while in some the effects of caries, or decay of the bones, the result of tedious and painful diseases, are apparent. Others have a light and spongy character, and are very fragile, which must have arisen from a want of

energy in the nutritive system, in consequence of a scrofulous affection.*

33. Human bones, and works of art, in caverns.—Bones of man, and fragments of ancient pottery, have been found in caves, both in France and Germany; a circumstance perfectly natural, since we are well aware that mankind, in a rude state, have been in the habit of living in caves, and traces of their having inhabited recesses, which had previously been the retreat of wild animals, were therefore to be expected. But as bones of extinct animals occurred with them, it was rashly assumed that they were coeval with each other; more accurate observations have, however, shown that the human remains were introduced at a subsequent period. We have historical proof that the early inhabitants of Europe often resided, or sought shelter in caves. Thus Florus records, that Cæsar ordered the inhabitants of Aquitania to be inclosed in the caverns to which they had retired. Many tribes of the Celtic race occupied these subterranean retreats, not only as a refuge in time of war, but also for shelter from cold; as magazines for their corn, and for the produce of the chase; and as places of concealment for the animals which they had domesticated. The bones of such of these people as perished, or were buried in these caverns,

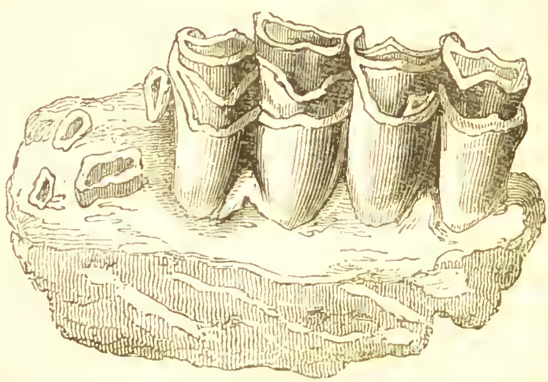
* Professor Walther, on the antiquity of diseases of bones; see Professor Jameson's Cuvier's Theory of the Earth. Edin. 1827.

would become blended with the mud, gravel, and débris of the animals already entombed; and a stalagmitical paste would in some places be formed by the infiltration of water, as at Bize, and would thus cement the whole into solid aggregates. We should therefore expect to find masses of stone, containing bones of the bear, and other extinct species, associated with human bones, fragments of pottery, terrestrial shells, and bones of animals of modern times.' Such are the contents of numerous caves, and the above explanation points out the mode in which such accumulations have taken place.*

34. OSSEOUS BRECCIA, OR BONE CONGLOMERATE.—The facts we have next to examine are even more extraordinary than those which have already been described; for the osseous remains which now claim our attention are not imbedded in gravel or clay, or collected together in caves, but are found in fissures of limestone, extending over an area of many hundred leagues, and occurring in rocks and islands, very remote from each other. The limestone presents but little variety, the substance in which the bones are enveloped is everywhere the same, and the fossil remains belong, with but few local exceptions, to similar species of animals. The rocks are split in every direction, and the fissures filled with what geologists term an osseous or bone-breccia; that is, bones, and

* Memoir by M. Desnoyer.

fragments of bones, held together by a calcareous cement or paste, in the same manner as the conglomerated shingle of Kemp-Town; or, to exemplify its nature by a still more familiar illustration, the mixture of mortar, pebbles, &c. employed in masonry, and called concrete. This cement is of a reddish brown, very much resembling common brick; and the bones are beautifully white, having in many instances their cavities lined with spar, as in these specimens from Gibraltar. In some examples the bones have undergone but little change; in others, the cells of the cancellated structure, are filled with calcareous matter, as you may observe in this specimen from Cerigo, (presented to me by Lady Mantell,) which is cut and polished, to show the internal structure of the bones.



Tab. 31.—Tooth of a ruminant in osseous breccia, from Gibraltar.

This tooth of a species of ruminant (Tab. 31) from

Gibraltar, resembles in its general appearance the teeth found in the Coombe-rock of the Brighton cliffs. But the stone to which it is attached is more compact, and partakes of the character of marble; it is of a dull red colour, mottled with white, and is susceptible of a good polish. This osseous breccia occurs on the northern shores of the Mediterranean; in the rock of Gibraltar; at Cette, Nice, and Antibes; in Dalmatia, and in the isles of Cerigo, Corsica, &c.; and in Sicily, Sardinia, and many parts of Germany. Each of these localities present highly interesting examples of the subject of our present inquiry.

35. The rock of Gibraltar.—The rock of Gibraltar, so well known from its historical and political importance, affords an admirable illustration of the phenomena under review; and, for the sake of brevity, I shall chiefly confine my observations to that celebrated spot. Gibraltar is situated on the Spanish side of the Mediterranean, being united to the main land by a narrow isthmus, which is about three-fourths of a mile broad, eight or ten feet above the level of the sea, and formed of consolidated sand. The rock stands on the western extremity of the area in which the osseous breccia occurs, and its greatest altitude is about 1,350 feet. It is in great part composed of a compact, bluish-grey marble, which, like most extensive limestone masses, is cavernous. The principal cavern, called St. Michael's, contains stalagmites and stalactites,

whieh when polished are of great beauty. In the fissures intersecting the roek, as well as in some of the eaves, a ealeareous coneretion, of a reddish-brown colour, oeeurs, whieh in some parts is a mere earthy mass, but in others is highly indurated. The bones are eommonly in a broken state, and but seldom water-worn; and the fragments of limestone, with whieh the fissures abound, are also angular, and have evidently, like the bones, fallen into the creviees at different periods, and been gradually inerusted and conglomerated by calcareous infiltrations. Snails and other land shells often occur impaeted in the solid breeeia; they belong to the existing speeies of the country. As the eoneretion is still in progress of formation, masses may be found with terrestrial shells unmixed with bones. The eementing material is very similar in the different loealities where the breccia has been observed; namely, at Cette, Niee, Antibes; in Dalmatia and Sardinia. The animal remains of the breceia are referable to several species, some of whieh are reeent and others extinet, of deer, antelope, rabbit, rat, mouse, &c. Bones of birds and of lizards have been discovered at Cette; and of lemmings,* and of the *lagomys*,† which now only exists in Siberia: it is but rarely that traces of carnivora are observed. No one ean fail to be struck with surprise at the

* Lemming, or Lapland marmot.

† Signifying rat-hare. A genus of animals which forms a link between the hare and the rat.

occurrence of these isolated, yet analogous phenomena, which surround the great basin of the Mediterranean—rocks of a uniform character, fissured and broken, their rents filled up with similar materials, and with the remains of the same species of animals. The occurrence of species, either extinct, or no longer inhabiting the same latitudes (as the *lagomys*), refers the period of the existence of these animals to the epoch of the mammoths and mastodons; and the absence of marine remains, and of the usual abrading effects of water, show that the breccia was formed on dry land, and not beneath the sea.

The rational explanation of these facts appears to be that which assumes the original union of these distant rocks and islands into a continent, or large island, which, like Calabria, was subject to repeated visitations of earthquakes; and that the animals which inhabited the country fell into the fissures thus produced, and were preserved by the calcareous infiltrations that were constantly in progress. Subsequent convulsions severed the country into rocks and insular masses, of which catastrophe the osseous conglomerates are the physical and only record.

36. OSSEOUS BRECCIA OF AUSTRALIA.—Caves and fissures, filled with osseous breccia, in the same manner with those I have described, have also been discovered in New Holland, to the westward of Sydney, near the banks of the Macquarrie river;

and it is not a little remarkable, that even the red ochreous colour of the European conglomerates prevails; the bones, however, belong to animals wholly distinct from any hitherto noticed in the preceding examples. Some of them are of living, others of extinct species, but all of them are referable to marsupial animals, as the *kangaroo*, *wombat*, *dasyurus*, &c. A portion of a large bone, found in a cave, is said to resemble the leg-bone of the hippopotamus, but this requires confirmation; it is, however, a subject worthy of attention, since the kangaroo is the largest animal now known in those regions. The fact that all the fossil animals of Australia hitherto discovered, are marsupial, that is, belong to the mammalia which carry their young in a pouch—a type of organization which is the peculiar feature of the existing races of the country—is also of great interest; for it proves that the present zoological character of those regions has prevailed from a very remote period.

37. RETROSPECT.—I must now bring to a close this examination of the ancient superficial deposits—those accumulations of alluvial matter, which taken as a whole, are referable to a far more early period than those which strictly belong to the modern or human epoch. And as in the former discourse I found it necessary to dwell on the discoveries of astronomy, to elucidate some of the physical changes of our planet; in the present I have summoned comparative anatomy to our aid,

and have endeavoured to point out the mode of induction pursued by the palæontologist, in his inquiries into the fossil remains of animal organization, by which he is enabled to call forth from their rocky sepulchres, the beings of past ages, and like the fabled sorcerer, give form and animation to the inhabitants of the tomb.

From the facts that have been presented to us in the course of this lecture, we arrive at the following important inferences:—

*First*—that the extinction of certain forms of animal existence is a law, which is not only in operation at the present moment, but has extended throughout the period comprehended in our present researches; and we have traced its influence from the partial extirpation of certain existing species, to the entire annihilation of many species and genera that once were contemporary with man; as well as to those which are known to have lived, and become extinct, prior to the creation of our race.

*Secondly*—that while in the modern marine and fluviatile accumulations, the remains of existing species of animals, and of man and his works, are entombed, in the ancient deposits of water-worn materials, those of larger mammalia alone are imbedded.

*Thirdly*—that the animal remains principally belong to extinct pachydermata, related to the elephant, hippopotamus, sloth, horse, deer, and other ruminants; and that these had for their contemporaries, bears, hyenas, tigers, and other carnivora of species now extinct.

*Fourthly*—that there was therefore a period immediately preceding the existence of man, when the earth teemed with large herbivorous animals, which roamed through the primeval forests unmolested, save by beasts of prey. Numerous species and entire genera have been swept away from the face of the earth,—some by sudden revolutions, others by a gradual extinction,—while many have been exterminated by man.

*Lastly*—that these various strata, whether formed in the beds of lakes or rivers, in estuaries, or in the depths of the ocean, have been elevated above the level of the sea, and now constitute fertile countries, supporting the busy population of the human race.

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I have thus endeavoured to interpret one page of the ancient physical history of our planet, and to explain the records of one epoch in geological chronology. We have entered upon the confines of the past, and already we find ourselves surrounded by an innumerable population of unknown types of being,—not as dim and shadowy phantoms of the imagination,—but in all the reality of form and structure, and bearing the impress of the mighty changes of which they constitute the imperishable memorials. We have again witnessed the effects of the continual mutations of the land and water,—

have seen that our present plains and valleys were submerged beneath the ocean, at a period when large mammalia, apparently unrestricted by existing limits of climate, were inhabitants of regions which are now no more—and we have obtained additional proof that—

> New worlds are still emerging from the deep,
> The old descending in their turn to rise!

Even in this early stage of our progress, we have conclusive evidence of the extinction of whole tribes of animals, equally admirable in their adaptation to the conditions in which they were placed, as the races which now exist. And delightful it is to the geologist, to find that this fact, which but a few years since was received with hesitation by most, and condemned and rejected by many, is now adduced by the moralist and the divine, as affording new proofs of the wisdom and overruling providence of the Eternal. Reflecting on these phenomena, the mind recalls the impressive exclamation of the poet—

> My heart is awed within me, when I think
> Of the great miracle which still goes on
> In silence round me—the perpetual work
> Of THY creation, finished, yet renewed
> For ever!

## LECTURE III.

1. Introductory remarks. 2. Substances composing the crust of the globe. 3. Crystallization. 4. Stratification. 5. Inclined and vertical strata. 6. Veins and faults. 7. Chronological arrangement of the strata. 8. Tertiary formations. 9. Classification of the tertiary strata. 10. Fossil shells. 11. Mineralogical characters of the tertiary system. 12. Newer tertiary or pliocene deposits. 13. Crag of Norfolk and Suffolk. 14. The Sub-Apennines. 15. Middle tertiary, or miocene deposits. 16. Lower tertiary, or eocene deposits. 17. The Paris basin. 18. The London basin. 19. The Isle of Sheppey. 20. Fossil fruits of the tertiary strata. 21. Upper marine, or Bagshot sand. 22. Artesian wells. 23. The Hampshire or Isle of Wight basin. 24. Alum bay. 25 London clay of the Hampshire basin. 26. Fresh-water strata of the Isle of Wight. 27. Organic remains of the Paris, London, and Hants basins. 28. Fossil plants and zoophytes. 29. Tertiary marine and fresh-water shells. 30. Nummulites, and other cephalopoda. 31. Crustacea and fishes. 32. Fossil birds. 33. Fossil animals of Paris. 34. Palæotheria and anoplotheria. 35. Fossil quadrumana, or monkeys. 36. Tertiary strata of Aix, in Provence. 37. Fossil insects. 38. Lacustrine formation of Œningen. 39. Fossil fishes of Monte Bolca. 40. Tertiary volcanoes of France. 41. Extinct volcanoes of Auvergne. 42. The crater of Puy de Come. 43. Mont Dor. 44. Fresh-water limestone and organic remains of Auvergne. 45. Summary of the geological phenomena of Auvergne. 46. Erosion of valleys by water-currents. 47. Extinct volcanoes of the Rhine. 48. Brown coal formation. 49. Other tertiary strata of Europe, North America, &c. 50. Altered tertiary strata of the Andes. 51. Tertiary saliferous deposit. 52. Retrospect. 53. Concluding remarks.

1. Introductory remarks.—It is my object in these Lectures to present a general view of the philosophy of Geology, rather than enter at length on the nature and distribution of the materials of which the crust of our globe is composed ; and to render the details of geological phenomena subser-

vient to an explanation of the laws which the Divine Author of all things has established for the renovation, maintenance, and government of the organic and inorganic kingdoms of Nature. Based as Geology is upon observations of the various physical changes which are now taking place, and on investigations of the natural records of those changes, in periods antecedent to all human history and tradition, the rocks and mountains are the alphabet, the book of Nature the volume, by which the student of this interesting department of science can best learn its important lessons. But to those who cannot examine Nature in her secret recesses, or accompany an experienced teacher to the valleys, or the mountain-tops, lectures illustrated by specimens and drawings, afford, perhaps, the best substitute for the more efficient and delightful mode of instruction.

That we may obtain a clear and comprehensive view of the vast field of inquiry that lies open before us, artificial classifications are necessary in this, as in other departments of science; and without assuming that the arrangement in which the various deposits are grouped by geologists, will not, in the progress of discovery, require considerable modification, it will be necessary, as an introduction to the subjects hereafter to be discussed, to place before you a tabular view of the formations in their presumed chronological order. At the same time it is necessary to bear in mind, that all classifications of this kind must necessarily involve arbitrary distinctions, and that very possibly it will hereafter be found that we may in some instances have classed as general, what may prove to be merely local phenomena; and have grouped together deposits, which farther investigations may show to be distinct, and separated from each other by vast periods of time. This consideration will not, however, affect those leading principles of modern Geology, which it is my present endeavour to render familiar to the intelligent but unscientific inquirer.

We will now take a general view of the nature of the mineral substances which enter into the composition of the crust of our globe, and briefly notice the laws which regulate the deposition of detritus in the beds of lakes and rivers, and in the depths of the ocean. But, as I have already remarked, it is not my intention to enter on these departments of Geology in detail; the works of Bakewell,* Lyell,† Phillips,‡

* "Introduction to Geology," by Robert Bakewell, Esq. 1 vol. 8vo. 5th edition. This excellent volume should be the first book in the library of the geological student.

† "The Principles of Geology," by Charles Lyell, Esq. F.R.S. 4 vols. 12mo. One of the most interesting works in the English language. "Elements of Geology." 1 vol. By the same author. 1838.

‡ "A Guide to Geology," by John Phillips, Esq. F.R.S. 1 vol. 12mo. The article on Geology, in the Encyclopedia Metropolitana, by the same excellent writer, is in my opinion the best scientific epitome of modern Geology that has yet appeared. "A Treatise on Geology," in 2 vols. foolscap 8vo. by the same author. 1839. A work of great merit.

De la Beche,* Burr,† and others, afford all the information on these subjects which the student can require.

2. SUBSTANCES COMPOSING THE CRUST OF THE GLOBE.—Every substance is composed of atoms of inconceivable minuteness, held together by a principle termed attraction or cohesion, and which is probably a modification of that influence, which, as it exists under other conditions in inorganic substances, is called electricity, galvanism, or magnetism; and in organized beings, nervous influence. As the different stages of solidity, fluidity, or vapour, in which every material body may exist, have been exemplified in the former lectures, we need only remark, that there are about sixteen substances, which in the present state of chemical knowledge are considered simple in themselves, and which, in their various combinations, constitute by far the largest amount of the gaseous, liquid, solid, organic, and inorganic matter of the earth. Of these, eight are non-metallic; viz. *oxygen*, *hydrogen*, *nitrogen*, *carbon*, *sulphur*, *chlorine*, *fluorine*, and *phosphorus*. There are also six metallic bases of alkalies and earths, namely, *silicium*, *alumine*,

* "A Geological Manual," by H. T. De la Beche, Esq. F.R.S. An admirable work of reference. "Researches in Theoretical Geology." A volume of considerable interest, affording a condensed and perspicuous view of the theories of modern geologists.

† "Elements of Practical Geology," by Frederick Burr, Esq. 1 vol. foolscap 8vo.

*potassium*, *sodium*, *magnesium*, and *calcium;* and two, the oxides of which are neither earths nor alkalies, namely, *iron* and *manganese*. The remaining metallic substances, copper, lead, zinc, arsenic, silver, gold, &c. are comparatively unimportant in a geological point of view.

The common sedimentary rocks are in a great measure composed either of lime, silex, or argillaceous earth; and they possess, what in mineralogical language is called, a *cleavage*, or peculiar fracture, which is distinct in each. Thus, if I take a flint and break it at random, you perceive that it presents a glassy or *conchoidal* fracture, a sharp cutting edge; and subdivide it as I may, it still retains the same character: but if I break a piece of chalk, the edge is not sharp or cutting, but blunt and dull, exhibiting what is called in mineralogy an *earthy* fracture. Again, if I shiver to pieces with my hammer this calcareous spar, every fragment presents, more or less distinctly, a rhomboidal form; so true is the remark, that we cannot break a stone but in one of nature's joinings.

3. Crystallization.—Crystallization may be defined a methodical arrangement of the particles of matter according to fixed laws. For instance—there are nearly 500 varieties of crystallized carbonate of lime, each crystal being composed of millions of atoms of the same compound substances, and having one invariable primary form—that of a rhomboid. Mechanical division is incapable of

altering this arrangement; break them as we may, we can only separate them into a rhomboidal figure; nor can this condition be altered except by chemical decomposition. If we pursue our investigations yet farther, analysis shows that every atom of these crystals consists of quicklime and carbonic acid, which are each made up of innumerable molecules. "Lime and carbonic acid are also themselves compounds, lime being composed of a metal called calcium and oxygen; and carbonic acid, of carbon and oxygen. Thus these ultimate particles of calcium, carbon, and oxygen, form the indivisible atoms into which all the secondary crystals of lime may be reduced."*

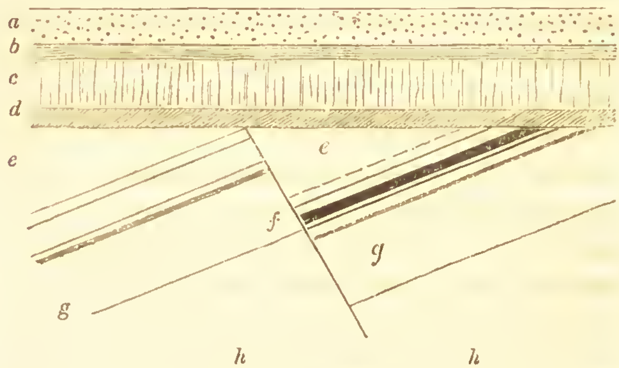
4. STRATIFICATION.—As our previous investigations have shown that the disintegration and solution of the most refractory, and apparently indestructible substances, by the conjoined effects of mechanical and chemical agency, are constantly in progress, we can at once proceed to the consideration of the manner in which the spoils of the ancient lands and seas have been accumulated, and converted into the rocks and strata of existing islands and continents. I have already adverted to the formation of beach and sand, and the deposition of mud and clay in layers or strata, and their subsequent consolidation into rocks. And here let me remind you, that *strata* are the successive layers or accumulations of detritus, spread over each

* Dr. Buckland's Bridgwater Essay.

other, in such manner as to allow of the partial consolidation of one bed, before it is covered by a deposition of the materials of another; and a rock is said to be *stratified*, when it presents the appearance of such divisions. The chalk cliffs, and the sandstone quarries in the south-east of England, afford excellent illustrations of this structure. The original direction of these layers must have been more or less horizontal, for this obvious reason, that in their fluid, or semi-fluid state, they would find their own level, and spread over the surface of the basin into which they flowed; and although they might partake of the inequalities of the depression in which they were deposited, yet this cause would not affect their general distribution. The strata when accumulated in very thin layers, resembling the seams formed by the leaves of a closed book, are termed *laminæ;* and this character very commonly prevails in fluviatile or river deposits: thus the shales, clays, and sandstones, of Tilgate Forest are laminated, and often bear the impress of the waters which have meandered over them (see pages 42, 43). The contemporaneous beds formed in the same oceanic basin, however they may maintain a general character over very extensive areas, must nevertheless vary considerably. At the present moment, the rivers flowing from different latitudes into our existing seas, must necessarily be producing in the same marine basin accumulations of a very dissimilar character; and the geographical distribution of the detritus, must be still more affected by the agency of those powerful currents, to which allusion has already been made (page 55). Bearing in mind these elements of variation in the depositions that may contemporaneously take place within the same oceanic basin, we shall be prepared to find similar discrepancies in the contents of the beds of the ancient seas.

5. Inclined and vertical strata.—But although the strata, whether accumulated in banks or ridges, or deposited in basins or depressions, have originally been consolidated in horizontal layers, yet this arrangement has frequently been disturbed by expansive forces from below, and the strata have been broken up, and thrown into every direction, from a slight degree of inclination, to a vertical position. The sections before us, (Plates 7, 8, 9, 10,) to which I shall hereafter have occasion to refer, exhibit strata in various states of displacement.

Although it is my wish to abstain as much as posible from technical language, yet as it cannot in all cases be avoided without much circumlocution, it will be convenient in this place to explain a few scientific terms which are commonly employed. Thus, parallel layers or strata, piled, as it were, horizontally upon each other, as *a*, *b*, *c*, *d*, in the following diagram (and in the *Section near Devizes*, Plate 9, No. II.) are said to be *conformable;* but when strata are superimposed on others which lie in a different direction, as the series *a*, *b*, *c*, *d*, on the beds *e*, *f*, *g*, *h*, (or in the natural section, Plate 9, No. III.) as if a set of horizontal volumes were




TAB. 32.—STRATIFICATION.

placed flat on the inclined edges of another series of books, they are, in geological language, in an *unconformable position.*

6. VEINS AND FAULTS.—But not only have the strata suffered change of position from the disturbing causes which we have shown are still in actual operation; they have also been rent and broken up, and exhibit cracks or fissures, which in rocks near the surface are sometimes filled, as we have already noticed, with bones, pebbles, and stalactitical concretions (page 178); and in those of more ancient epochs, with eruptions of melted matter, and veins of metalliferous ores. The term *fault* is applied to those fractures and displacements of the strata which are

aeeompanied with the subsidenee of one part of a mass and the elevation of another. This is exemplified in the seetion of the earboniferous strata, (Tab. 32, *e*, *f*, *g*, *h*,) where the layers, or seams of eoal, have been shifted to a higher level, although both sides of the roek remain in apposition ; *f* marks the line of fault. Stratifieation, in faet, may be eompared with the operation of ereeting a building ; strata of elay being eomparable to beds of mortar, those of harder roeks to layers of briek ; while the fissures, veins, and faults are analogous to the eraeks, sinkings, and displaeements produeed by the settling of different portions of the whole edifiee.

7. CHRONOLOGICAL ARRANGEMENT OF THE STRATA.—In the aneient alluvial beds of gravel, sand, and marl, eontaining the remains of gigantic mammalia, whieh formed the prineipal subjeet of the last leeture, but few indieations of stratifieation oeeur ; those deposits, for the most part, bearing the eharaeter of materials transported by the sea or by river eurrents, or aeeumulated in estuaries, and thrown up in bays and ereeks by the waves, rather than that of tranquil depositions. The formations whieh sueeeed, we shall find eomposed of regularly stratified roeks, but interspersed here and there with alluvial debris. The plan of the strata before you (Plate 7) is intended to present a general view of the various systems of roeks, from the most reeent to the most aneient. For more detailed explanations and seetions, reference

may be made to the works already noticed; and particularly to the admirable systematic diagram of the formations, by that veteran geologist, Mr. Webster, which forms the frontispiece of Dr. Buckland's Bridgewater Essay.

It will here be necessary to premise, that there are three elements of classification applicable to stratified rocks; namely, 1st, their mineral structure; 2dly, their order of superposition; and 3dly, the nature of the organic remains which they contain: the following arrangement is in accordance with these principles.*

## CHRONOLOGICAL ARRANGEMENT OF THE STRATA.

*Commencing with the uppermost or newest Deposits.*

### FOSSILIFEROUS STRATA.

I. MODERN AND ANCIENT ALLUVIUM.—Comprising the modern and ancient superficial deposits, described in the previous lectures. The *modern* are characterised by the remains of man and contemporaneous animals and plants; the *ancient*, by an immense proportion of large mammalia and carnivora, of species and genera, both recent and extinct.

II. THE TERTIARY SYSTEM.—An extensive series, comprising groups of marine and lacustrine deposits, characterised by the remains of animals and vegetables, the greater portion of which are extinct. Volcanoes of great extent were in activity during this epoch.

* See Professor Sedgwick's Synopsis of the English Series of Stratified Rocks inferior to the old Red Sandstone. *Proceedings of the Geological Society*, vol ii. p. 76.

## Secondary Formations.

III. The chalk, or cretaceous system.—A marine formation, comprising beds of limestone, sandstone, marl, and clays, abounding in remains of zoophytes, mollusca, cephalopoda, echinodermata, fishes, &c.; drifted wood, and marine plants; with crocodiles, turtles, and extinct reptiles.

IV. The wealden.—Comprising the weald clay, the strata of Tilgate Forest, and of Hastings, and the limestones and clays of Purbeck. A freshwater formation, evidently the delta of some ancient river; characterised by an abundance of the remains of enormous and peculiar reptiles, namely, the iguanodon, hylæosaurus, megalosaurus, plesiosaurus, crocodile, &c.; of terrestrial plants, freshwater mollusca, and *birds.*

V. The oolite.—A marine formation of vast extent, consisting of limestones and clays, abounding in marine shells, corals, fishes, and reptiles, both terrestrial and marine. Land plants of peculiar species, *and the remains of two or more genera of* MAMMALIA.

VI. The lias.—A series of clays, shales, and limestones, with marine shells, cephalopoda, crinoidea, and fishes. Reptiles, particularly of two extinct genera, the *plesiosaurus* and *ichthyosaurus*, in immense numbers. Drifted wood and plants.

VII. The saliferous, or new red sandstone system.—Comprising marls, sandstones, and conglomerates, frequently of a red colour, with shells, corals, and plants; fishes and reptiles. This series forms the grand depository of rock-salt.

VIII. The carboniferous, or coal system.—Shales, ironstones, millstone grit, freshwater limestone, and immense beds of coal. This system is characterised by innumerable remains of land and aquatic plants, of a tropical character, and belonging to extinct species and genera; with fishes, reptiles, and insects.

IX. The old red sandstone system.*—Consisting of various strata of conglomerate, sandstone, marl, and limestone; the prevailing colour of a chocolate red; contains shells, corals, and fishes, many of which are peculiar.

X. The silurian system.—Composed of marine limestones, shales, sandstones, and calcareous flags; abounding in shells, many of new forms; and swarming with corals, crinoidea, and trilobites.

XI. The Cambrian, or grauwacke system.—Consists principally of a largely developed series of slate rocks and conglomerates, containing shells and corals.

### Metamorphic Rocks.

*Destitute of Organic Remains.*

*Stratified.*

XII. The mica schist.—Sedimentary rocks, altered by high temperature; mica slate, quartz rock, crystalline limestone, gneiss, and hornblende schist, &c., exhibiting no traces of organic remains.

XIII. The gneiss system.—Formed of gneiss, sienite, and quartz rock, alternating with clay slate, mica schist, &c.

*Unstratified.*

XIV. Granite.—In amorphous masses and veins; porphyry, serpentine, trap, &c.

The proportionate thickness of the rocks hitherto examined in England is estimated as follows;† but

* *Vide* "Geology of the Silurian Region," 2 vols. 4to. with numerous plates and map, by Roderick Impey Murchison, Esq. V.P.G.S. The most splendid and important work on British Geology that has yet appeared.

† Professor Phillips.

the statement must be viewed only as an approximative calculation.

| | |
|---|---|
| Tertiary system . . . . | 2,000 feet. |
| Cretaceous . . . . . . . | 1,100 „ |
| Oolitic and lias . . . . . . | 2,500 „ |
| Saliferous . . . . . . . . | 2,000 „ |
| Carboniferous . . . . . . | 10,000 „ |
| Old red sandstone . . . . | 9,000* „ |
| Primary rocks . . . . . . | 20,000 „ |

I have represented in this diagram (Plate 7) intrusions of the ancient melted rocks, as serpentine, porphyry, trap, and granite, into the sedimentary strata; and metalliferous and granitic veins in the granite, to which I shall hereafter have occasion to refer. At present it will only be necessary to mention, that the leading features of this arrangement may be recognised in every considerable extent of country throughout the world; but the subdivisions are more local, and cannot be generally maintained, for reasons which must be sufficiently obvious, after what has already been advanced. From this general view of the physical records of the mutations which the crust of our globe has undergone, we learn how numerous and important are the phenomena comprised within the sphere of geological inquiry, and how vain is the attempt to offer more than an epitome of its wonders in the brief space allotted to a popular course of lectures.

8. TERTIARY FORMATIONS.—We now enter

* Mr. Murchison.

upon the consideration of the tertiary formations, those deposits of the seas, rivers, and lakes, which are referable to the period immediately antecedent to the existence of the mammoth and mastodon, and subsequent to the deposition and consolidation of the chalk. The discoveries of MM. Cuvier and Brongniart, about twenty years since, in the immediate vicinity of Paris, first directed the attention of geologists to the important series of strata which is now distinguished by the name of tertiary (see p. 18). The animals whose fossil bones abound in the gypsum quarries of Montmartre, and belong to extinct genera of mammalia, were by the genius of Cuvier, again, as it were, called into existence, and the philosophers of Europe saw with astonishment, whole tribes of unknown and extraordinary types of being, disinterred from rocks and mountains, which had hitherto been considered as possessing no scientific interest. Analogous strata, some of a marine, and others of a lacustrine or fluviatile character, have since been discovered in numerous localities in the continents of Europe and America, forming a series so extensive, and requiring such a lapse of time for its production, that the chalk, hitherto considered as comparatively modern, is carried back to a period of immense geological antiquity. The tertiary system may be said to constitute a series of formations which link together the present and the past; for while the most ancient contain organic remains related to those of the secondary formations, the most recent insensibly glide into the modern deposits, and contain remains of many existing species of animals and plants, associated with forms that are now blotted out for ever. Mr. Lyell has adopted a classification of the tertiary strata, founded on the proportion of recent species of animals which they contain; and as shells occur in many of the strata in great abundance, and in an excellent state of preservation, those types of animal organization have been selected for the distinctive characters of the subdivisions into which, for the convenience of study, he separates these deposits. In the present state of our knowledge, this arrangement is of great utility, but it appears probable that it may require considerable modification, or, perhaps, hereafter be altogether abandoned with the progress of geological research; for it cannot be doubted, that strata in which no recent species have yet been found, may yield them to more accurate and extended observations.

9. Classification of the tertiary strata. —According to this classification the tertiary system forms four principal groups, each of which is characterised by the relative proportion of recent and extinct species of shells which it contains; and a nomenclature has been adopted to denote the characters upon which the arrangement is founded. These divisions are as follow:—

1. The pliocene (*signifying more new or recent*).—Tertiary strata, in which the shells are for

the most part recent, with about ten per cent. of extinct species; these beds are subdivided into the newer and older *pliocene:*

2. THE MIOCENE (*denoting less recent*).—Containing a small proportion, about twenty per cent., of recent species of shells.

3. EOCENE (*signifying the dawn of recent*, in allusion to the first appearance of recent species).—Containing very few recent species, perhaps not more than three or four per cent.

The marine are associated with a like number of freshwater formations, and the general characters of the tertiary system are alternations of marine with lacustrine strata. The districts occupied by these beds in Europe, are exceedingly variable in extent, as Mr. Lyell has shown in a very ingenious map of the tertiary seas;* and it appears certain, that during the epoch of their formation, there were areas which were alternately the sites of freshwater lakes and inland seas, and that these changes were dependent on oscillations in the relative level of the land and water.

10. FOSSIL SHELLS.—The geological evidence afforded by the remains of animals and plants has already been fully exemplified; but our remarks have hitherto in a great measure been confined to the fossilized skeletons of terrestrial quadrupeds; the shells of mollusca, however, from their durability, often escape obliteration under circumstances

* Mr. Lyell's Principles of Geology, vol. i. p. 214.

in which all traces of the higher orders of animals are lost. In loose sandy strata, they occur in a high degree of perfection; in mud and clay, in a fragile state; in some instances they are silicified; and many limestones are wholly composed of their remains, cemented together by calcareous matter. Molluscous animals* are divided into *mollusca*, properly so called, which are covered with a shell, as snails, periwinkles, &c.; and *conchifera*,† having a shell with two valves, as the oyster, scallop, &c. The former are of a higher organization than the latter, having eyes, and a distinct nervous system; the latter have neither eyes nor head, and are therefore called *acephala*.‡ Some genera of mollusca are herbivorous, living exclusively on vegetables; others are carnivorous; and many have a retractile proboscis, furnished with a rasp, by which they can perforate wood, shells, stone, and other substances. The shells of the carnivorous testacea are also generally provided with a channelled or grooved beak for the reception of the fleshy syphon by which the sea water is conveyed to the respiratory organs (Tab. 38. Fig. 3, 4, 5); while the herbivorous have the opening of the shell entire (Tab. 39, Fig. 3, 5, 6, 7). Some tribes are exclusively marine, others live only in fresh-water, while many are restricted to the brackish waters of estuaries. Their geographical distribution is alike various: certain

* Soft-bodied animals. † Shell-bearing animals.
‡ Having no head.

forms (the *cephalopoda*) inhabit deep waters only, and are provided with an apparatus by which they can rise to the surface; while others are littoral, that is, live only in the shallows along the sea shores; many exist in quiet, others in turbulent waters; some are gregarious, like the oyster, while others occur singly or in small groups. All these varieties of condition are more or less strongly impressed on their shelly coverings, which may be considered as their external skeletons; and the experienced conchologist is enabled by the peculiar characters of the shell, at once, to determine the economy and habits of the animal, and consequently the physical conditions in which it was placed.* In this point of view, fossil shells become objects of the highest importance to the geologist, since they are frequently the only records of the former condition of our planet. But I must return from this digression, and proceed to the consideration of the phenomena presented by the several groups of the tertiary formations.

11. MINERALOGICAL CHARACTERS OF THE TERTIARY SYSTEM.—The predominating characters of the tertiary system, as I have already mentioned, are alternations of marine beds with those of lacustrine and freshwater origin. A large proportion of the strata is arenaceous, having intervening clays and marls. Shingles, the remains of ancient sea-

* See an interesting paper on Shells, by Mr. Gray, of the British Museum. Philosophical Transactions.

beaches, abound in some localities, and form either a conglomerate or puddingstone, as that of Hertfordshire (page 88); or a ferruginous breccia, as at Castle Hill, near Newhaven, on the Sussex coast. The ruins of the chalk are everywhere recognisable in the beds of water-worn flints, which contain shells and zoophytes peculiar to the cretaceous system. Large boulders of sandstone are of frequent occurrence, and may, perhaps, be referred to the newest beds of the series. In the vicinity of Brighton, blocks of ferruginous breccia are scattered over the surface of the Downs, and masses of quartzose sandstone, of a saccharine structure, are seen at Falmer, and in Stanmer Park: a remarkable rock of this kind formerly existed in Goldstone Bottom, near Brighton, but is now destroyed. In most of the gravel beds around London there are numerous blocks of siliceous breccia and conglomerate, of which there are many of considerable magnitude on the grounds of John Allnutt, Esq. of Clapham Common. In some of the tertiary formations, limestone predominates, and alternates with sands and marls of great variety and brilliancy of colour; beds of gypsum, and silicious nodules closely resembling the flints of the chalk, also occur. Such are the general features of this system of deposits, which I shall now examine more in detail.

The distribution of the tertiary strata over Europe, appears to be in areas more or less well defined; in our own island, there are the basins of

London and Hampshire, and the remains of other beds in Yorkshire, and in Norfolk and Suffolk. In France, the metropolis is situated within the confines of a tertiary basin; and in the south and north of that country, extensive tracts are formed of these deposits; in Auvergne, where they are associated with ancient volcanic eruptions, they constitute a district of unrivalled geological interest. In the Sub-Apennines, they are largely developed; and in other parts of Sicily and Italy they insensibly pass into vast beds, which are still in progress of formation.

12. Newer tertiary, or pliocene deposits. —From the large proportion of recent species of shells which occur in some of the pliocene strata, the beds have the appearance of a modern aggregate, as the extensive and beautiful collection from Palermo, before us (for which I am indebted to the kindness of the Marquis of Northampton, P.R.S.) well displays. A low range of hills, rising to an elevation of about 200 feet above the level of the Mediterranean, immediately behind Palermo, is in a great measure constituted of coarse limestone, formed of friable shells, which are frequently in an admirable state of preservation; white and brittle in general, but in some examples preserving their markings and natural polish. The elegant and picturesque manner in which they are occasionally grouped together, renders them objects of great beauty and interest. These shells, with but

very few exceptions, belong to species still living in the adjacent seas; a proof that when the limestone was formed, the same condition of the basin of the Mediterranean existed as at present, and continued uninfluenced by the elevation of this portion of its ancient bed. In other parts of Sicily, limestone, blue marl, with shelly calcareous breccia, and gypseous clay, intermingled with volcanic products, occur. The *Val di Noto* is particularly mentioned by Mr. Lyell, as presenting a remarkable assemblage of deposits;* and I will quote his lucid and highly graphic description. "The rising grounds of the Val di Noto are separated from the cone of Etna, and the marine strata on which it rests, by the plain of Catania, which is elevated above the level of the sea, and watered by the Simeto. The traveller passing from Catania to Syracuse, by way of Sortina and the valley of Pentalica, may observe many deep sections of these modern formations, which rise into hills from one to two thousand feet in height, entirely composed of sedimentary strata, with recent shells; these are associated with volcanic rocks. The whole series of strata, exclusively of the volcanic products, is divisible into three principal groups. 1. The *uppermost*, compact limestone in laminated strata, with recent shells; total thickness, from 700 to 800 feet. 2. Calcareous sandstone, with schistose limestone. 3. Laminated marls and blue clays."

* Principles of Geology, vol. iii. p. 388.

The above groups contain shells and zoophytes of the same species as those from Palermo which I have just noticed. The large scallop or pecten (*Pecten jacobæus*), which at the present day is profusely strewn on the Sicilian shores, is also beautifully preserved, and abundant in the compact limestone. Leaves of plants and stems of reeds, are of common occurrence.

13. CRAG OF NORFOLK AND SUFFOLK.—On the eastern coasts of Essex, Norfolk, and Suffolk, beds of sand and gravel, abounding in shells and corals, are superposed on the blue clay lying on the chalk, and are distinguished by the name of *Crag*, a provincial term signifying gravel. The late Mr. Parkinson first described these strata, and in the "Organic Remains of a Former World,"* figured a shell which was formerly in much request among collectors, the Essex reversed whelk (*Fusus contrarius*), in which the spiral convolutions pass from right to left, instead of in the opposite and ordinary direction. Here are several beautiful examples of this fossil, collected by Sir Woodbine Parish; they all have the deep ferruginous colour which so commonly prevails in the fossils of the Crag. The Crag first appears at Walton Nase, in Essex, and constitutes the upper part of the cliffs on both sides of Hanwell, varying from a few feet to thirty or forty in thickness. It extends inland along the Suffolk and Norfolk coast, forming a tract of at

* Vol. iii. pl. 6. fig. 5.

least forty miles in length; near Ipswich it is spread over a considerable area, and abounds in shells and other marine exuviæ. The fossils which I now place before you are from collections made by the late Mrs. E. Cobbold, of Holywell Park, near Ipswich; Sir Woodbine Parish; the late Samuel Woodward, Esq.;* and Edward Charlesworth, Esq., whose recent investigations have thrown much light on the zoological characters of these deposits. The Crag is divided into two groups; the lowermost, or coralline Crag, which is composed of loose sand, and abounds in corals, sponges, and shells, in so perfect a state as to indicate that they lived and died on the spot where their remains are entombed. This series is upwards of fifty feet in thickness, and rests upon a layer of blue clay, which will hereafter be noticed. The uppermost, or *Red Crag*, so called from its deep ferruginous colour, consists of sand with shells which are generally broken and water-worn; the Norfolk Crag appears to be principally composed of these upper beds. The fossils of the Crag are extremely numerous; they consist of several hundred species of marine shells, some of extinct, but the greater part of species now existing in the German Ocean; of corals, sponges, and more than a hundred species of microscopic foraminifera; with teeth and scales of fishes. The collection of *Crag* shells on the table was some years since examined

* Author of "Outlines of the GEOLOGY of NORFOLK."

by Mr. Lyell, and M. Deshayes, a distinguished Freneh naturalist, by whom more than half the speeies were eonsidered to be of extinet forms; and the remainder identieal with speeies whieh now inhabit the German Oeean.*

14. THE SUB-APENNINES. — The Apennines, that ehain of hills whieh extends through the Italian peninsula, are flanked, both on the side of the Adriatie and the Mediterranean, by the Sub-Apennines, a low range eomposed of tertiary marls, sands, and eonglomerates, abounding in marine shells of those speeies and genera whieh prove that some of the strata were eotemporaneous with the Crag, and that others are referable to a more aneient epoeh. These beds have resulted from the waste of the secondary roeks, whieh form the Apennines, and were dry land before those strata were deposited.†

15. MIDDLE TERTIARY, OR MIOCENE DEPOSITS. —In the elassification of Mr. Lyell, the term *Miocene* designates those tertiary beds in whieh reeent speeies of shells oeeur, but in a mueh less proportion than in the preeeding division; seldom amounting to one-fifth of the whole. As there are no good types of this group in Great Britain, I shall merely observe, that marine and fresh-water

* Principles of Geology, vol. iv. p. 71.

† Brocehi, an eminent Italian naturalist, published many years sinee a valuable work on the fossil shells of the Sub-Apennines.

deposits possessing the characters here defined occur near Bordeaux and Montpellier; and in Piedmont, Styria, Hungary, and other parts of the European continent; but in many instances the strata seem to merge into one or other term of the series. I proceed therefore to the consideration of the *Eocene*, or those tertiary strata which are of the highest antiquity, and are found deposited in basins or depressions of the chalk, where that formation constitutes the fundamental rock of the country. Every step of our progress will now be replete with the deepest interest, and new and singular forms of being will appear before us. I shall pass rapidly over the stratigraphical character of these rocks, that our attention may be more fully directed to the extraordinary organic remains which they inclose.

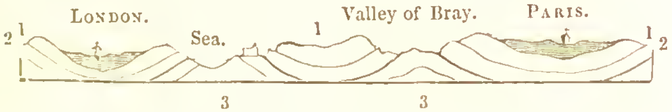
16. Lower tertiary, or eocene deposits.—I propose, in the first place, to describe the geographical distribution and general characters of a few principal groups of the older tertiary strata; secondly, to investigate the nature of the more remarkable fossil animals and plants; and lastly, to survey those regions of central France, of the Rhine, and of South America, which have been the scenes of active volcanoes during the tertiary epoch.

It may be regarded as a singular coincidence, that the capitals of Great Britain and France are located on strata of the same geological epoch. Paris is situated on a vast alternation of marine and fresh-water beds, lying in a depression of the chalk; the latter forming the boundary of the area in which the city is placed. London is built on clays, sands, and shingles, also filling up a basin of the chalk, which skirts the area of the tertiary strata on the south, but is open to the sea on the east. In Hampshire, a series of contemporaneous lacustrine


Tab. 33.—Tertiary basins of Paris, London, and Hants.

*(From Mr. Webster's Map in the Geological Transactions.)*

deposits, with interspersions of marine remains, in like manner rest upon the chalk, and constitute the basin of the Isle of Wight. The relative situation and comparative extent of these three groups are shown in the map (Tab. 33), reduced from that which accompanied Mr. Webster's first announcement of the characters of the British tertiary formations; and this section, by Mr. Lyell (Tab. 34), from Hertfordshire across the British Channel, to Sens in France, explains the position of the London and Paris basins, and the underlying secondary formations.




TAB. 34.—SECTION FROM HERTS, TO SENS, IN FRANCE.
(*From Lyell's Elements of Geology.*)
1. Chalk. 2. Green sand. 3. Wealden.
The shaded sites of London and Paris indicate the tertiary deposits.

17. THE PARIS BASIN.—The Paris basin is from east to west about 100 miles in extent, and 180 from north-east to south-west; the total thickness of the beds, or, to use other terms, the depths passed through to reach the chalk, varying from one to several hundred feet.

The strata, commencing with the lowermost, or most ancient, present the following characters:—

1. *The lowermost.* Chalk flints, broken, and partially rolled, sometimes conglomerated into ferruginous breccia. A layer of this kind is very common on the South Downs, immediately under the turf.

2. *Plastic clay, and sand.* Clay and sand, with fresh-water shells, drifted wood, lignite, leaves, and

fruits; intercalated with limestone containing marine shells.

3. *Silicious limestone,* fresh-water and terrestrial shells and plants, and marine limestone, or *Calcaire grossier,* a coarse compact limestone, passing into calcareous sand, and abounding in marine shells.— These beds often alternate, and are considered by M. Constant Prevost to be contemporaneous formations; the marine strata having been formed in those parts of the basin which were open to the sea; and the fresh-water limestone, by mineral waters poured into the bay from the south; the continent being situated then, as now, to the south, and the ocean to the north. Partial layers of *milliolite* limestone,* almost entirely composed of microscopic chambered shells, occur in this part of the basin.

4. *Gypseous marls, and limestones,* with bones of animals, and fresh-water shells of fluviatile origin. These are supposed to have been discharged by a river which flowed into the gulf; the gypsum being precipitated from water holding sulphate of lime in solution, in the same manner as the travertine or calcareous tufa, of which we have already spoken (page 56.)

5. *Upper marine formation,* consisting of marls, micaceous and quartzose sand, with beds of sandstone abounding in marine shells.

* So called from its inclosing immense quantities of a minute shell, named *Milliolite.*

6. *Upper fresh-water marls*, with interstratified layers of flint, containing seed-vessels of aquatic plants (*Charæ*), and animal and vegetable remains. These beds are attributed to lakes or marshes, which existed after the marine sands had filled up the basin.

From this rapid sketch, we perceive that the strata which occupy the Paris basin, have been produced by a succession of changes that readily admits of explanation by the principles so ably enforced by Hutton, Playfair, and Lyell, and explained in the previous lecture. Here we have an ancient gulf of the chalk, which was open to the sea on one side, while on the other it was supplied by rivers charged with the spoils of the country through which they flowed, and carrying down the remains of animals and plants, with land and river shells; and there were occasional introductions of mineral waters. Changes in the relative level of the land and sea took place, and thus admitted of new accumulations upon the previous deposits; lastly, the country was elevated to its present altitude above the sea. Mutations of this kind, as we have already seen, are in progress at the present moment, and afford a satisfactory elucidation of these interesting phenomena. I reserve my remarks on the fossils of the Paris basin to the next section, and pass to the examination of the analogous beds in our own island.

18. The London basin.—The tertiary strata on which the metropolis of England is situated are

spread over a considerable area, which is bounded on the south by the North Downs; extends on the west beyond High-elm hill, in Berkshire; and on the north-west is flanked by the Chalk hills of Wiltshire, Berkshire, Oxfordshire, Buckinghamshire, and Hertfordshire. On the east it is open to the sea; the Isle of Sheppey, situated in the mouth of the Thames, being an outlier of the same deposit.* It spreads over Essex, a considerable part of Suffolk, Epping and Hainault forests, the whole of Middlesex, and a portion of Bucks. In the immediate vicinity of the metropolis, a stiff clay of a bluish-black colour, abounding in marine remains, constitutes the great mass of the materials which fill up this ancient gulf of the ocean. Immediately upon the chalk, however, there occur thick beds of sand and clay, called Plastic clay (from its analogy to the *Argile Plastique* of the Paris basin), in which fresh-water shells, plants, and drifted wood, have been found in some localities. In other instances, layers of green sand lie upon the chalk, which at Reading contain immense quantities of oyster-shells: a similar accumulation of shells has been observed at Headley, in Surrey, a few miles from Reigate, by Mr. Peter Martin, jun. of that town. At Bromley, in Kent, there is a bed of oyster-shells with pebbles of chalk-flints, which are cemented together by a calcareous deposit into a remarkable

* See Mr. Webster's paper in the Geological Transactions; and Conybeare and Phillips's Geology of England and Wales.

conglomerate, in much request for grottoes and ornamental rock-work. The London clay is found immediately beneath the gravel which so generally forms the sub-soil of the metropolis; it is of great extent, and varies from 300 to 600 feet in thickness. This clay forms a dark, tough soil, and has occasional intermixtures of green and ferruginous sand, and variegated clays. It abounds in spheroidal nodules of indurated argillaceous limestone, internally filled by veins of calcareous spar, or sulphate of barytes, disposed in a radiating manner from the centre of the nodule to the circumference. From the appearance of partitions which this character confers, these concretions are commonly known by the name of *Septaria*: shells and other organic remains frequently form the nucleus of these nodules, which are used in prodigious quantities for cement. The specimens on the table are from Highgate and Bognor; two from the latter locality, presented to me by Dr. Hall, contain beautiful examples of an extinct species of nautilus. The septaria are commonly disposed in horizontal lines, and lie at unequal distances from each other. Brilliant sulphuret of iron abounds in the clay, and is seen in this septarium, as well as in many of the organic remains. Crystallized sulphate of lime, or selenite, is also common in these as in other argillaceous strata. The cuttings through Highgate Hill, to form the archway; the excavations in the Regent's Park; and more recently the tunnels earried through a part of the same ridge of clay at Primrose Hill, in the line of the Birmingham railroad; and the explorations, by wells, over the whole area around London, have brought to light sueh prodigious quantities of organie remains, that the fossils of this deposit are almost universally known. The admirable work of the late Mr. Sowerby, called early attention to these testaceous remains, the first plate in his Mineral Conehology being devoted to the "Nautili of the London Basin." Immense numbers of marine shells of extinet speeics; erabs, lobsters, and other crustaeea; teeth of sharks, and remains of many genera of fishes; bones of erocodiles and turtles; leaves, fruits, stems of plants, and rolled trunks of trees, perforated by boring shells,—occur throughout these strata, but are located in greater abundanee in some spots than in others. The elay and gravel pits at Woolwieh, on the banks of the Thames, abound in univalve shells; and at Plumstead, Bexley, and other places, marine bivalve shells oeeur in clay, and in indurated argillaceous limestone.

19. The Isle of Sheppey.—The Isle of Sheppey is entirely composed of the London clay, and the thiekness of the beds is upwards of 550 feet. It has long been eelebrated for its organic remains; and I may observe, that the diseovery of seed-vessels and stems of plants in pyritous elay, in a visit whieh I made to Queenborough, when a youth, tended to confirm my early taste for geologieal researehes.

The cliffs on the north of the island are about 200 feet high, and consist of clay, abounding in *septaria*, which are washed out of the cliffs by the action of the sea, and are collected for cement. The organic remains are, however, unfortunately so strongly impregnated with pyrites, that the collector often finds the choicest fossil fruits in his cabinet, like the fabled apples of the Dead Sea, one moment perfect and brilliant, and the next decomposed and changed to dust, leaving only an efflorescent sulphate of iron. The same species of animal and vegetable remains that are found in the blue clay of the metropolis, abound in profusion in the Isle of Sheppey.

20. Fossil fruits of the tertiary strata. —Seed-vessels, and stems and branches of trees, of a tropical character, probably drifted by currents into the gulf of the London basin, occur in such abundance and variety, that the existence of a group of spice islands seems necessary to account for so vast an accumulation of vegetable productions. The seed-vessels found at Sheppey are referable to several hundred species; some are related to the cardamom, date, areca, cocoa; and one species of berry bears much resemblance to the fruit of the coffee. The wood found in the Sheppey clay is generally of a dark colour, with the ligneous fibres and circles of growth well developed; it is often veined with brilliant pyrites, and the fissures and cavities are frequently filled with that mineral. It

is rarely that any considerable mass of wood is found free from the ravages of a species of teredo, resembling the reeent *teredo navalis*, or *borer*, which inhabits the seas of the West India islands. The tubular shells sometimes remain, but their cavities, as well as the perforations in the wood, are filled with pyrites, indurated elay, argillaceous limestone, or calcareous spar; and speeimens, when eut and polished, exhibit interesting sections of the meandering grooves of the teredines. In this specimen, from the banks of the canal in the Regent's Park, the grain of the wood, with the shells, and their exeavations, are beautifully displayed.

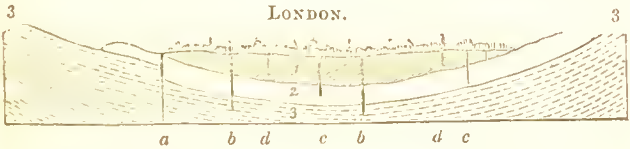
21. UPPER MARINE, or BAGSHOT SAND.—At Highgate and Hampstead, Purbright and Frimley Heaths, in Surrey, and on Bagshot Heath, extensive beds of sand occur, with but few traces of organic remains; those hitherto observed are principally casts of marine shells. In cutting through the summit of Goldworth hill, four miles north of Guildford, on the line of the London and Southampton railway, teeth and other remains of several genera of fishes have lately been diseovered; the teeth of sharks, and the palates of rays, are the most numerous. One large tooth of a saw-fish, affords the first well-authenticated example of the genus *pristris*, in a fossil state, in England; and there have also been found teeth of several new genera of cartilaginous fishes, related to *psammodus*.* The

* Proceedings of the Geological Society, vol. ii. p. 687.

boulders and masses of sandstone, which are abundant in some of the chalk valleys and on the flanks of the Downs, are called Sarsden-stone, or Druid sandstone, from being the principal material employed in the construction of Stonehenge, and other Druidical monuments; they are supposed to have been derived from the sand-beds, which overlie the London clay in the places above named; they may, however, have belonged to the sands which lie between the clay and chalk. The wastes and unproductive heaths around the metropolis, are sites of these arenaceous deposits, which also form the subsoil of that charming and picturesque spot, Hampstead Heath. The gravel and shingle, associated with the sands, have unquestionably been derived from the ruins of the chalk formation.

22. Artesian wells.—As from the alternation of porous, arenaceous strata, with stiff or impervious beds of clay, the artificial perennial fountains, called Artesian wells, are of frequent occurrence in the vicinity of the metropolis, I will in this place offer a few remarks on the phenomena of springs. The descent of moisture from the atmosphere upon the earth, and its escape into the basin of the ocean, by the agency of streams and rivers, were noticed in the first lecture. The rain falling on a gravelly or porous soil, will, of course, descend through it, till its progress is arrested by a clayey or impervious stratum, which will thus form a natural tank or reservoir, collect the water, and a subter-

ranean pool or canal will be the result, according to the direction and configuration of the upper surface of the clay. This state of things will continue, till, by an increased supply, the water rises above the level of the basin, or channel, and overflowing, escapes, either through the porous strata, or by fissures in the solid rocks, to another level. If the course of the waters be subterranean, the softer beds are worn away, and chasms or caverns are thus formed, hence rivers and streams, of great extent, occur in many of our mines; but if the water finds its way to the surface, a spring bursts forth. This is the nature of all springs, except those which arise from great depths, and probably originate from the condensation of steam, evolved through fissures by volcanic agency; such are the thermal waters of many countries. Streams impregnated with the mineral substances contained in the strata through which they flow, are called mineral waters. Those in the tertiary strata near Epsom, contain sulphate of magnesia, whence the name of Epsom salt, given to this substance wherever it occurs. But strata which are pervious, frequently alternate with others which are not so; or may form a basin, the area of which is partially filled with clay, through which water cannot pass: in such a case, it is obvious that the bed of sand beneath the clay, fed by the rain which descends on the uncovered margin of the basin, must form a reservoir, and the water gradually accumulate beneath the central plateau of clay, through which it cannot escape. If this bed of clay be penetrated, either by natural or artificial means, the water must necessarily rise to the surface, and may be even thrown up in a jet to an altitude which will depend on the level of the fluid in the subterranean reservoir; such is the phenomenon observable in the Artesian wells around London. Argillaceous strata are generally found to be dry within; and the blue clay confines the water contained in the sands beneath; the engineer perforates the clay, introduces tubes, and taps the natural tank; by this method, the perennial fountains of Tooting, Hammersmith, Fulham, &c. have been obtained.* The wells sunk into the London




Tab. 35.—Plan of the Artesian wells near London.

1. The London clay. 2. Plastic clay and sand. 3. The chalk.

clay (Tab. 35, 1, *d*, *d*,) yield no water; but the sandy strata alternating with the clays, afford a supply, the quantity and quality of which depend on the nature of the rock. The borings, which reach

* Consult Dr. Buckland's Bridgewater Essay, p. 561; and an admirable Essay on Artesian Wells, in that excellent scientific periodical, the Mining Journal, conducted by H. English, Esq., F.G.S.

the sands of the plastic clay (Tab. 35, 2, *c*, *c*,) furnish good soft-water; and the wells that extend to the chalk (Tab. 35, 3, *a*, *b*, *b*,) afford an abundant supply, which often rises to the surface in a perennial fountain, for the chalk rests on an impervious bed of marl and clay. Of the practical utility of geological knowledge, even in the common operation of sinking a well, I once had a striking proof. A gentleman residing in Sussex, on the borders of the Forest Ridge, who had seen with admiration the perpetual springs in the environs of the metropolis, determined to form one in his grounds at —— Park. Accordingly, a person conversant with the construction of the Artesian wells around London was employed, and the necessary apparatus obtained: but the engineer, being wholly ignorant of the nature of the strata, carried his operations to a great depth, through the beds of the wealden sand of which the district is composed, and, of course, without success, as the least geological knowledge of the strata of the country would have foretold. The undertaking, after considerable labour and expense, was abandoned.

23. The Hampshire, or Isle of Wight basin.—The London basin presents but little analogy to the alternate marine and freshwater deposits of that of Paris; but in Hampshire and the Isle of Wight, there is an extensive suite of tertiary strata, composed of clays, sands, and limestones, containing freshwater, with intercalations of marine remains.

This group extends over a considerable district. On the east, a small outlier of the lower beds appears at Castle Hill, near Newhaven, in Sussex;* but to the westward of Brighton, beyond Worthing, the London clay rises to the surface, and forms the sub-soil between the Downs and the sea-shore. The inland boundary stretches by Chichester, Emsworth, and Southampton, to Dorchester; and the clay is spread over the whole area of the New Forest and the Trough of Poole, being flanked by the chalk on the north, north-east, and north-west, and open to the sea on the south. The Isle of Wight, although now separated from the main land, is a disrupted mass of the formations of the south-east of England; the chalk basin having been broken up, and the chalk and the superimposed sands, clays, and gravel, in some instances, thrown into a vertical position. A remarkable and well-known instance of this phenomenon occurs at Alum Bay, so called from the alum, formerly extracted from the decomposing pyrites, with which the clay abounds.

24. Alum bay.—This sketch (Tab. 36) conveys a general outline of the bay; *a*, represents the vertical chalk; *b*, *b*, the corresponding tertiary strata, consisting of sands and clays of an infinite variety of colour, and containing abundance of shells. Advantage is taken of the diversified tints of the sands to represent, in glass vessels, landscapes of the island,

* Geology of the South-East of England, p. 53.

which are sold to visitors. The appearance of Alum Bay is thus graphically described by Mr. Webster, whose able memoir on the strata above the English chalk, formed a new era in British Geology, and raised our tertiary series to an importance equal to


Tab. 36.—Alum bay, Isle of Wight.

*a*, vertical strata of chalk. *b*, *b*, vertical tertiary strata.

that of the Paris basin. "The clays and sands of Alum Bay afford one of the most interesting natural sections imaginable. They exhibit the actual state of the strata immediately above the chalk, before any change took place in the position of the latter. For, although the beds of which they are composed are quite vertical, yet from the nature and variety of their composition, and the regularity and number of their alternations, no one who views them can doubt that they have suffered no change, except that of having been moved with the chalk from a horizontal to a vertical position. These sands and clays present every variety of colour of green, yellow, red, crimson, ferruginous, white, black, and brown." Beds of pipe-clay also occur; some of which contain layers of wood-coal, with branches and leaves. The coal burns with difficulty, and emits a strong sulphureous smell; masses are constantly drifted by the sea and thrown on the shore near Brighton, where this substance was formerly used as fuel by the poorer inhabitants.*

25. London clay of the Hampshire basin.—The London clay extends over the greater portion of the area of the Hampshire basin, its peculiar fossils abounding in many localities. Castle Hill, near Newhaven, which has been already mentioned, is a series of sands, marls, and clays, with beds of oyster-shells and of shingle that occupy the upper part of the hill, and rest upon the chalk which forms the lowermost fifty feet of the cliff. The sub-sulphate of *alumine*,† a mineral substance peculiar to this locality, occurs in the ochraceous clay which is in immediate contact with the chalk. Selenite, or crystallized gypsum, abounds in the gypseous marls; a layer of surturbrand, or wood-coal, a few inches thick, contains impressions of land-

* See Geology of the South Downs, p. 261.

† British Mineralogy, Tab. 499. Geology of the South-East of England, p. 56.

plants;* and the argillaceous beds contain marine and fresh-water shells in such abundance, that some of them are mere masses of compressed shells, held together by argillaceous earth. The oysters are consolidated into coarse stone, and where pebbles enter into the composition of this concrete, a close resemblance is presented to the Bromley oyster conglomerate (p. 214). Teeth of sharks have been collected in these strata. At Chimting Castle, near Seaford, on the eastern escarpment of the valley of the Ouse, olive-green sand, and a ferruginous conglomerate of chalk-flints, lie upon the chalk, thus determining the original extension of the tertiary beds along the Sussex coast.† Westward from Brighton, the London clay is perceived near Worthing, emerging from beneath those newer deposits which, as we have already seen, contain remains of elephants. At Bognor, an arenaceous limestone, full of the usual shells of the *Calcaire grossier* and London clay,‡ constitutes a group of low rocks, which in another century will probably have entirely disappeared. The beauty and variety of the shells, particularly of the nautili, and of the perforated fossil wood, render these organic remains objects of great attraction. In the blue clay at Bracklesham Bay, and at Stubbington, on the western coast of Sussex, fossil shells may be obtained at low-water

* Fossils of the South Downs, Pl. viii. figs. 1, 2, 3, 4.

† Geology of the South-East of England, p. 62.

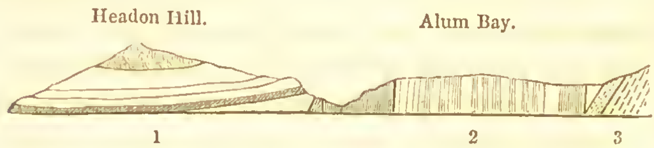
‡ Fossils of the South Downs, p. 271.

in profusion; and Hordwell Cliff, in Hampshire, has so long been celebrated for similar productions, that its elegant shells are seen in almost every collection of organic remains. In all these localities the shells are of the same genera and species with those of the contemporaneous deposits of France.

26. Fresh-water strata of the Isle of Wight.—The great peculiarity and interest of the Isle of Wight basin, as compared with that of London, consists in the existence of strata containing almost exclusively fresh-water shells and remains of the same kind of animals as those which occur in the vicinity of Paris. Mr. Webster arranged the tertiary beds of Hampshire, in the following manner:—1st. *Lowermost;* Plastic clay and sand. 2d. London clay. 3d. Fresh-water deposits,—sandy calcareous marls, with immense quantities of fresh-water shells. 4th. Clay and marl, abounding in marine shells; very generally of different species from those of the London clay. 5th. Upper fresh-water deposit; yellowish white marl, and calcareous limestone, employed for building; nearly sixty feet in thickness, and almost one entire mass of fresh-water shells.

Subsequent observations have shown that the above subdivisions have been made from too partial a view of the phenomena, and that the entire suite of deposits must be regarded as a fresh-water formation, into which there have been occasional irruptions of the sea.

The above series is well developed at Headon Hill, where the fresh-water strata, which succeed those of Alum Bay, lie in a nearly horizontal




TAB. 37.—SECTION OF HEADON HILL AND ALUM BAY.

Fig. 1. The horizontal fresh-water beds of Headon Hill. 2. Vertical tertiary strata of Alum Bay. 3. Almost vertical beds of chalk.

direction. At Binstead, near Calbourne, and Morley, quarries have been opened in the fresh-water limestone; and bones and teeth of *Anoplotheria*, *Palæotheria*, of the *Chiropotamus* an animal allied to the *Peccari*, and of a species of *Moschus*, have been discovered.

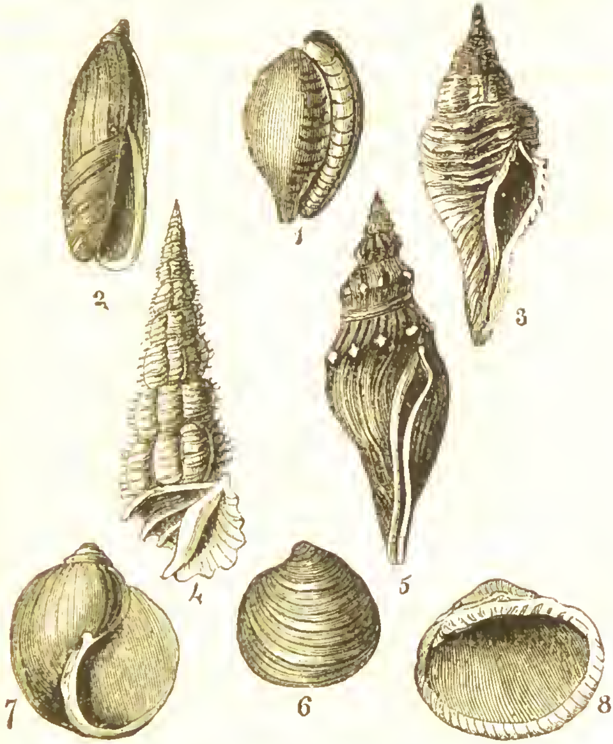
27. ORGANIC REMAINS OF THE PARIS, LONDON, AND HANTS BASINS.—So numerous are the relics of the inhabitants of the ancient land and water entombed in the strata which we have thus cursorily surveyed, that I can only attempt a brief description of the organic remains. To condense my remarks as much as possible, I shall select the fossils of the Paris basin as the types of the zoology of the older tertiary epoch, and include notices of such species as, occurring in British and other localities, may be requisite for the illustration of the subject.

28. Fossil plants and zoophytes.—Fossil wood occurs in vast abundance, particularly in the state of large trunks and branches, which appear to have been drifted, and are full of perforations inclosing shells of boring mollusca. Bognor rocks, the clay around London, of the Isle of Sheppey, &c. abound in specimens of this kind. The wood is dicotyledonous, that is, like the oak, ash, &c.; its mode of increase was by annular circles of growth, as will be explained in the lecture on Fossil Botany. Leaves and stems of palms have been found in the Paris basin, and in the Isle of Sheppey, &c.; and a trunk of a tree related to the palm, nearly four feet in diameter, at Soissons. Fruits belonging to trees allied to the areca, pine, fir, cocoa-tree, &c. have been discovered in several localities. Accumulations of vegetable matter, in the state of lignite or *brown coal*, occur at Bovey Tracey in Devonshire, and in various parts of France, the Netherlands, &c. Amber, and a substance which has been called Highgate resin, are occasionally imbedded in these deposits.

Zoophytes. — Polyparia, or corals, occur in some of the marine strata, but they are not very numerous; several species of turbinolia, caryophyllia, fungia, and other corals, are figured and described by authors. I have a few specimens from Grignon. The modern tertiary (those of Palermo) abound in various kinds of flustra and spongia.

29. Marine and fresh-water shells of the tertiary strata. — So numerous are the shells of the tertiary epoch, already determined by naturalists, that they exceed one-half of the known living species, amounting to nearly three thousand. We have already seen that some of the strata are almost entirely composed of these remains in a broken and compressed state: at Newhaven, in Sussex, many seams in the argillaceous beds wholly consist of shell-dust. In other localities the shells occur in the most perfect state; and Grignon, a few leagues from Paris, has long been celebrated for its beautiful fossils, hundreds of species of shells peculiar to the older tertiary strata having been collected in one spot alone: these belong to the *Calcaire grossier*, and many of the species occur in the London and Hampshire basins, and Bognor rocks. I have selected a few specimens, from those in my possession, to convey an idea of their usual characters and appearance. (Tab. 38.)

Although, in mentioning the names of these shells, I do not expect that any but the scientific inquirer will endeavour to fix them on the memory, yet it is useful to point out to you the characters which prevail in these tertiary beds; for, as I have already stated, certain fossils are peculiar to certain strata, and the experienced geologist can often, at a glance, determine the relative antiquity of a deposit by an examination of a few species of shells. The whole of these forms must be familiar to you, because they belong to genera which have species still living in our present seas. The *Cypræa*, or cowry (fig. 1), and the *Ancilla*, or olive, (fig. 2),




TAB. 38.—MARINE SHELLS OF THE PARIS BASIN.

Fig. 1. Cypræa inflata. 2. Ancilla canalifera. 3. Fusus uniplicatus. 4. Cerithium lamellosum. 5. Pleurotoma dentata. 6. Lucina sulcata. 7. Ampullaria sigaretina. 8. Pectunculus angusti-costatus.

are well-known types. The *Cerithium* (fig. 4) belongs to a genus which is most abundant in the sands of the Paris basin, and is remarkable for the elegance, number, and variety of the species, which exceed by three times those of their living analogues. The *Cerithium giganteum* attains a considerable magnitude. Some masses of the Bognor rock are almost wholly composed of a species of *Pectunculus.* The *Ampullaria* (Tab. 38, fig. 7) abounds at Grignon, and is commonly in a beautiful state of freshness. You will recollect that in most of the carnivorous species the aperture of the shell is channelled. (Tab. 38, figs. 2, 3, 4, 5.)

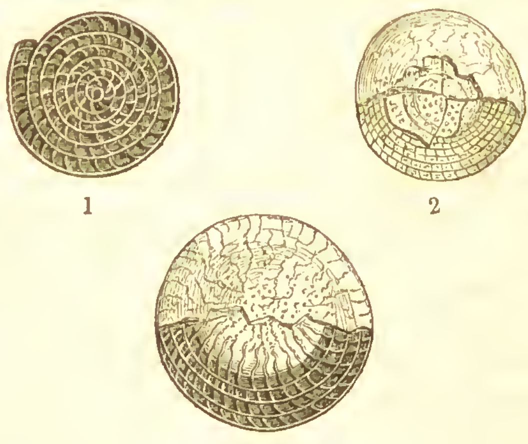

TAB. 39.—FRESH-WATER SHELLS OF THE PARIS BASIN.

Figs. 1, 2. Bulimus conicus. 3, 4. Cyclostoma mumia. 5. Lymnea effilea. 6, 7, 8. Planorbis.

FRESH-WATER TERTIARY SHELLS.—It has already been observed, that the shells of the mollusca which inhabit fresh water, possess characters by which they may be distinguished from the marine species. This small selection from the fresh-water beds of Paris will serve to elucidate my observations. The general appearance of these shells will bring to your recollection the species which inhabit our ponds and rivers; particularly the large thin snail (*lymnea*, fig. 5) and the discoidal shells (*planorbis*, figs. 6, 7, 8); while figs. 3 and 4 (*cyclostoma*) resemble a species often found on the banks of lakes. At Headon Hill, and at Binstead in the Isle of Wight, the clay and limestone are filled with the remains of several species of *planorbis* and *lymnea*.

30. Nummulites, and other cephalopoda.—Several species of nautilus abound in the tertiary strata; those inclosed in the septaria, or indurated argillaceous nodules, of the London clay at Highgate, Sheppey, and Bognor, possess considerable beauty, and admit of being cut in sections, which admirably display the internal structure of the original. I shall, however, defer an explanation of their mechanism to the subsequent lecture, when analogous fossil genera will come under our notice. My observations will now be restricted to an interesting division of the *Cephalopoda* (as those mollusca are termed whose head is surrounded by the organs of motion, or feet), called *Foraminifera*, which comprehends many genera, and several hundred species, the greater part being microscopic,

and analogous to the recent forms which inhabit the Mediterranean. These bodies are entirely distinct from the testaceous habitations of snails, periwinkles, &c.: they are, in truth, not an external, but an internal apparatus; and it is supposed, that, in addition to their having served as a point of attachment and support to the soft body of the animal, they acted as a buoy, which could be made heavier or lighter at pleasure, and by which the animal was enabled either to sink




TAB. 40.—NUMMULITES, FROM THE GREAT PYRAMID OF EGYPT.

*(Collected by Dr. George Hall, of Brighton.)*

Fig. 1. Transverse section of a Nummulite. 2, 3. Nummulites, with the external plate partially removed.

or swim. The fossil called *Nummulite* (from its resemblance to a coin) affords a beautiful illustration of the structure of these bodies. It is of a lenticular, discoidal form, and varies in size from a mere point to an inch and a half in diameter. The outer surface is generally smooth, and marked with fine undulating lines. On splitting the shell transversely, it is found to consist of several coils, which are divided into a great many cells or chambers by oblique partitions (Tab. 40, fig. 1), apparently having no communication with each other, but which the animal, probably, had the power of filling with fluid, or air, through foramina or pores; whence the name of the order. To Dr. George Hall (physician to the Sussex Hospital), I am indebted for the specimens exhibiting this structure, which I now place before you (Tab. 40); they are from the limestone formed of nummulites, held together by calcareous cement, which constitutes the foundation rock of the Great Pyramid of Egypt, and of which that structure is in part composed. Strabo alludes to the nummulites of the pyramids, under the supposition that they are lentils which had been scattered about by the workmen, and become converted into stone.* This polished, silicious pebble, presented me by the Marquess of Northampton, is also from Egypt; the markings on the surface are sections of the inclosed shells. The nummulite is one of the most widely diffused of fossil shells, its remains forming whole chains of

* See Wilkinson's Manners and Customs of the Ancient Egyptians, vol. ii. p. 371.

calcareous hills: it is not confined to the tertiary, but occurs also in the secondary formations, and constitutes immense beds in the Alps and Pyrenees. The blue clay at Bracklesham and at Stubbington, and the calcareous sandstone of Emsworth and Bognor, in Sussex, abound in nummulites. In North America, the limestone which occurs near Suggsville, and forms a range of hills about 300 feet in height, is entirely composed of one species of nummulite. This limestone is porous, and contains spheroidal cavities formed by the decomposition of the organic remains.*

31. Crustacea and fishes.—Crabs and lobsters, of species related to the recent, several of which are described by MM. Brongniart and Desmarest, in their beautiful work on Fossil Crustacea, have been found in the clay of Highgate, and in the Isle of Sheppey. The external configuration of the shell or crustaceous covering of these animals being in conformity to the viscera which they inclose and are intended to protect, the naturalist is able, by an accurate acquaintance with the characters of the living species, to point out the relation or difference of the fossil, even though the carapace or buckler alone remains; and the size and situation of the heart, stomach, &c. may thus be readily determined. This remarkably fine crab

* *Nummulites Mantellii* of Dr. Morton. See Synopsis of the Organic Remains of the Cretaceous Group of North America. 8vo, with numerous plates. Philadelphia.

(Tab. 41) is from Malta; it shows the state of perfection in which fossil crustacea are sometimes discovered.

Tab. 41.—Fossil crab, from Malta.*

*(Cancer Macrochelus.)*

Seven or eight species of fishes, of extinct genera, have been found in the Paris basin alone. The teeth of several kinds of sharks (*lamna*) occur every where, and are known by the name of "birds' bills." In the clay of Sheppey and London, beautiful fossil fishes have been found, the scales possessing a metallic lustre, from an impregnation of sulphuret of iron. But I must pass cursorily over these remains, as well as those of crocodiles, turtles, and tortoises, which are imbedded in these deposits.

32. Fossil birds.—In the gypseous building-stone of Montmartre, M. Cuvier found many bones which possessed characters peculiar to those of

* One half the size of the original.

birds; and after much research he was enabled to determine several fossil species, related to the pelican, sea-lark, curlew, woodcock, buzzard, owl, and quail. In some examples there are indications of the feathers, and even of the air-tubes. Sometimes the skeleton is wanting, and a pellicle of a dark brown substance alone points out the configuration of the original (Tab. 42).

Not only are the skeletons and feathers of birds found in the tertiary strata, but even the eggs of

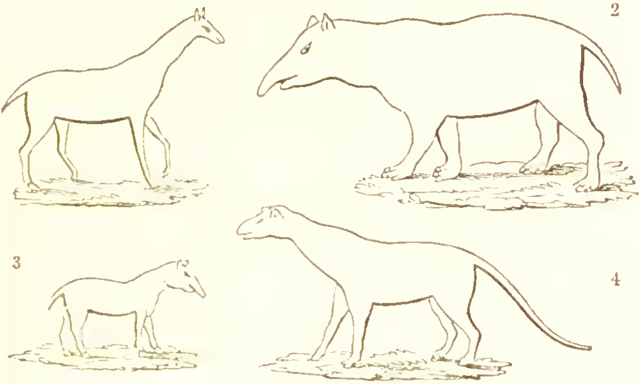
TAB. 42.—FOSSIL BIRD, FROM MONTMARTRE.

aquatic species occur in the lacustrine limestone of Auvergne. I have already noticed that eggs of turtles are daily in the course of fossilization on the shores of the Isle of Ascension.

33. Fossil animals of Paris. — We have next to consider the fossil remains of the mammalia whose skeletons were entombed in the mud of the waters which formerly occupied the area of Paris, and which the genius of Cuvier has again, as it were, called into existence. The forms of these extinct creatures are now as familiar to us as our domestic animals, and even the names of *palæotheria* and *anoplotheria* are almost become household words. The gypsum quarries which are spread over the flanks of Montmartre have long been known to afford fossil bones; but, although specimens occasionally attracted the notice of the naturalists of Paris, and collections were formed, yet no one appears to have suspected the mine of wonders which the rocks contained, till the curiosity of Cuvier was awakened by the inspection of a large collection of these bones, after he had successfully applied the laws of comparative anatomy to the investigation of the fossil elephants and mammoths. He had previously paid little or no attention to the partial accounts of fossil bones found in the vicinity of Paris, although in 1768, Guettard had figured and described many bones and teeth. Cuvier now, however, perceived that a new world was open to his researches, and he soon, by zeal and energy, obtained an extensive collection, and found himself (to use his own expression) in a charnel-house, surrounded by a confused

mass of broken skeletons of a great variety of animals. To arrange each fragment in its proper place, and to restore order to these heaps of ruins, seemed at first a hopeless task; but a knowledge of the immutable laws by which the organization of animal existence is governed, soon enabled him to assign to each bone, and even fragment of bone, its proper place in the skeleton; and the forms of beings hitherto unseen by mortal eye arose before him. "I cannot," says this illustrious philosopher, in all the enthusiasm of successful genius, "express my delight on finding how the application of one principle was instantly followed by the most triumphant results. The essential character of a tooth, and its relation to the skull, being determined, immediately all the other elements of the fabric fell into their places; and the vertebræ, ribs, bones of the legs, thighs, and feet, seemed to arrange themselves even without my bidding, and precisely in the manner which I had predicted." The principles of comparative anatomy enunciated in the second lecture will have prepared you for this result; and I therefore need not dwell on the application of the laws of co-relation of structure by which the animals of the Paris basin have been restored. This group of figures, (Tab. 43) from Cuvier's restorations, is indeed a splendid triumph of Palæontology.

The examination of the fossil teeth at once showed that the animals were herbivorous, the enamel and ivory being disposed in the manner already explained (page 132); the crown of the tooth is composed of two or three simple crescents, as in certain



TAB. 43.—ANIMALS OF THE TERTIARY EPOCH.

Fig. 1. Anoplotherium gracile. 2. Palæotherium magnum. 3. P. minus. 4. Anoplotherium commune.

pachydermata; thus differing from the ruminants, which have double crescents, and each four lines of enamel. Following out the inquiry, Cuvier at length established that the great proportion of bones and teeth belonged to two extinct genera of pachydermata, which bear an affinity to the tapir, rhinoceros, and hippopotamus. Almost every one is familiar with the form and habits of the two last animals; but the tapir is not so well known. Of this genus there are several living species, all natives of tropical climes. The Malay tapir (a stuffed specimen of which is placed on the lobby of the British

Museum,) sometimes attains eight feet in length, and six in circumference. It has a flexible proboscis, a few inches long; its general appearance is heavy and massive, resembling that of the hog. The eyes are small, the ears roundish; the skin is thick and firm, and covered with stout hair; the tail short. It inhabits the banks of lakes and rivers, and has been observed to walk under water, but never to swim.*

34. Palæotheria, and anoplotheria.— These fossil animals are divided into the genera palæotherium (*ancient wild beast*); and anoplotherium (*unarmed wild beast*), so named from the absence of canine teeth. I will now describe the species here figured.

Palæotherium magnum, fig. 2. This animal was of the size of a horse, but more thick and clumsy; it had a massive head, and short extremities. It was like a large tapir, but with differences in the teeth, and a toe less on the fore feet. It must have been from four to five feet in height, which is about equal to that of the rhinoceros of Java. From the conformation of the nasal bones, no doubt can exist of its having been furnished with a short proboscis, or trunk.

Palæotherium minus, fig. 3. Of the size of the roebuck. This creature had light and slender limbs, with the general configuration of the tapir.

Anoplotherium gracile, fig. 1. This animal,

* Griffiths' Animal Kingdom, vol. iii. p. 434.

to which Cuvier gave the name of *gracile*, from its elegant proportions, was of the size and form of a gazelle, and must have lived after the manner of the deer and antelopes.

ANOPLOTHERIUM COMMUNE, fig. 4; was of the height of a wild boar, but of a more elongated form, and had a long and thick tail like a kangaroo. the feet having two large toes like the ruminants. It seems probable that it could swim with facility, and frequented the lakes, in the beds of which its bones were deposited.

More than fifty genera of extinct mammalia have been discovered in the older tertiary, and their characters determined by Baron Cuvier. Some are related to the animals we have just described; as the *anthracotherium*, (so named from the discovery of its remains in the anthracite, or lignite of Cadibona,) which held an intermediate place between the hog and hippopotamus. Six or seven species of carnivora, an opossum, a squirrel, dormouse, &c. have also been found in the Paris basin.

In the miocene strata of Touraine and of Darmstadt, there is an intermixture of the remains of the above extinct mammalia with those of the mastodon, and of genera which still exist. Mr. Murchison has discovered in Bavaria, bones of the palæotherium, anoplotherium, anthracotherium, mastodon, rhinoceros, hippopotamus, ox, horse, bear, &c. in lacustrine deposits, associated with fresh-water and land shells.

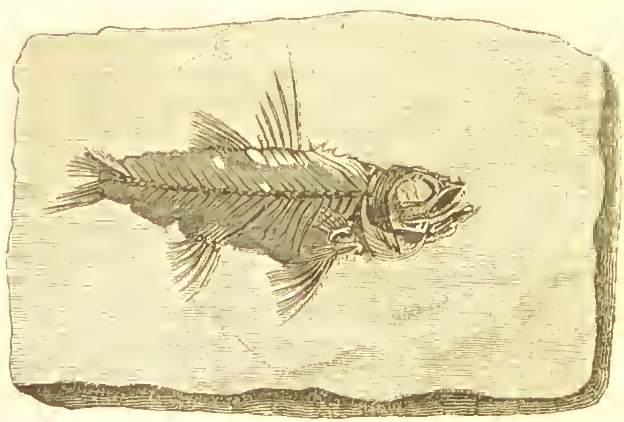
35. FOSSIL QUADRUMANA OR MONKEYS.—At Sausan, in the department of Gers, are tertiary strata, abounding in remains of the rhinoeeros, horse, palæotherium, anoplotherium, and other mammalia. M. Lastel has diseovered a jaw of a *monkcy*, whieh, from its proportions, must have belonged to an animal about three feet in height. The molar teeth in the speeimen are worn, and very elosely resemble those of a man of middle age, redueed to half their natural size. Another fossil monkey has been found in the Sub-Himalaya hills near the Sutlej, by Captain Cautly, assoeiated with remains of mastodons, elephants, eroeodiles, turtles, &c. This speeimen is the right half of the upper jaw, to whieh a portion of the orbit of the eye remains attaehed, and this alone is suffieient to enable an anatomist to determine the nature of the original, the orbits of the *quadrumana* being peeuliar. Without entering upon details uninteresting to the general inquirer, it may be stated that evidenee is thus afforded of the existenee of a gigantie speeies of monkey, eontemporaneously with the paehydermata whose fossil remains oceur in the Sub-Himalayas. The important faet is therefore now established, that animals of that type of organization whieh most nearly resembles the human, existed in the ancient tertiary epoehs.*

* THE QUADRUMANA.—These animals eome nearest to man in the form and proportion of their skeleton, and of their separate bones; in the general disposition of their museular system,

36. Tertiary strata of Aix, in Provence. (See Pl. 9, section iii.)—A group of tertiary strata, remarkable as well for their mineralogical character as for the organic remains which they contain, occurs near Aix, a town in Provence, which is situated upon a thick deposit of tertiary conglomerate. The series on the northern side of the valley consists of—1. Tertiary breccia, (see Pl. 9, fig. 3,) lying unconformably on the secondary rocks of oolite and green sand, which are nearly vertical. 2. Marl, with fishes and insects. 3. Gypsum and gypseous marls, with fishes and insects; leaves of

and its adaptation for a semi-erect position of the body; in their great cerebral organization, the perfection and equable development of their senses; their intellectual capacity, and complicated instincts. These most elevated of all inferior animals are fitted to select, obtain, and digest the succulent ripe fruits of trees, and are destined to inhabit the rich and shady forests of tropical climates. They leave to the squirrels and the sloths the buds and leaves; to the ponderous elephant and rhinoceros the branches and the stems; and to the beavers, and other rodentia, the dark bark of the trees. Their delicate organization is adapted only for the richest products of the vegetable kingdom; and the soft and nutritious quality of their food is suitable to the broad enamelled crowns of their molar teeth, which are studded with rounded tubercles: their stomach is simple. With a high cerebral and muscular development, corresponding with their elevated rank in the scale of beings, and the position of their food, they are the most agile and sportive of all mammalia; and they are provided with prehensile organs at every point; their teeth, tail, feet, and hands assist in their agile movements, and in their boundings from branch to branch, and from tree to tree.—*Dr. Grant's Lectures on Comparative Anatomy.*

palms, and other plants; fresh-water univalve and bivalve shells, particularly a species of *cyclas* in great abundance. The *cyclas* inhabits lakes and marshes, and therefore positively denotes the lacustrine character of the deposits. 4. Fresh-water limestone. To the south, extending towards Toulon, are lacustrine strata of red marl, with compact limestone inclosing shells, gyrogonites, &c. Still farther to the south, beds of grey fresh-water limestone appear; and at Fuveau, (see the section, Pl. 9, fig. 3,) a series of blue limestone, shale, and coal, which is extensively worked. Fresh-water



TAB. 44.—FOSSIL FISH, FROM AIX.
(*Smerdis minutus.*)
(Drawn by Miss Jane Allnutt.)

shells, seed vessels of *charæ*, and other vegetable remains, occur in abundance in the coal-beds and intermediate layers of shale. The section employed to illustrate this description is copied from a rough sketch made by Mr. Lyell on the spot, when he first visited this interesting locality; and which I greatly value on that account.

The marls, as you may perceive, in this extensive suite of specimens, collected by Messrs. Lyell and Murchison, (whose admirable Memoir* on these strata is of high interest,) are very finely laminated, and contain insects and fishes in a remarkable state of preservation. The fishes are very numerous; one small species in particular (*smerdis minutus*, Tab. 44,) is found grouped together in every variety of form and position.

37. Fossil insects.—But the fossil insects are the most extraordinary relics, appearing as fresh as if enveloped but yesterday. This beautiful example, presented to me by Mrs. Murchison, shows the exquisite preservation of these delicate objects. A few of the most interesting forms are here delineated on a slightly enlarged scale, from the plate accompanying the paper to which I have referred.†

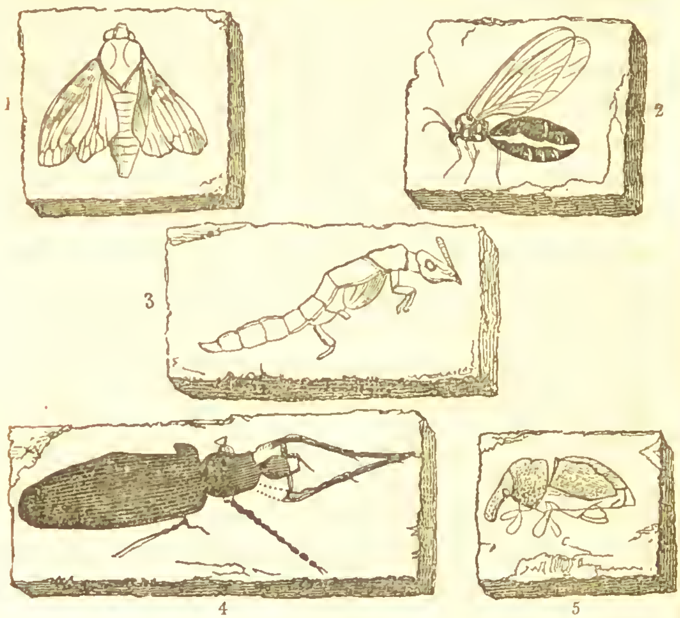
All the insects belong to existing genera, and only one species is aquatic.‡ The anterior *tarsi* are generally obscure, or distorted; but in some specimens the claws are visible, and the sculpture, and even a degree of local colouring are

* On the Freshwater Formation of Aix, in Provence, by C. Lyell, and R. I. Murchison, Esqrs.

† Jameson's Edinburgh Journal, for 1829. Pl. VI.

‡ Principles of Geology, vol. iii. p. 211.

preserved. The nerves of the wings in the *diptera*, and even the pubescence on the head, are distinctly seen. Several of the beetles have the wings ex-



TAB. 45.—FOSSIL INSECTS FROM AIX, IN PROVENCE.

Fig. 1. Tettigonia spumaria. 2. Mycetophila, imbedded while in the act of walking; the articulations of the body distended by pressure. 3. Lathrobium. 4. Allied to Penthetria holosericea. The hinder legs are broken off, and one of them is reversed, so that the *tarsi* nearly touch the thigh; the *palpi* are long and perfect; the *antennæ* remarkably distinct. 5. Liparus, resembling L. punctatus.

tended beyond the *elytra*, as if they had fallen into the water while on the wing, and had made an effort to escape by flight. M. Marcel de Serres has enumerated nearly seventy genera of insects, and a few *arachnides*, or spiders. The most curious fact is, that *some of the insects are identical with species which now inhabit Provence.* It seems probable that these insects were brought together from different localities by floods, and mountain streams; yet, as Mr. Curtis observes, all of them might have inhabited moist and shady forests. The laminated marls contain also the coverings of a fresh-water crustacea, called *cypris*, which swarms in our pools and stagnant waters, and must be familiar to all who have seen the exhibition of the oxy-hydrogen microscope; living specimens being commonly shown, and appearing somewhat like the head and feet of a flea protruding from an oval case or shield, and swimming by means of their fine *cilia*, which resemble pencils of hair. These crustacea shed their cases, some of which are silicious and others calcareous, annually, and the surface of the mud spread over the bottoms of lakes is often strewed with their relics. The marls of Aix, as well as of many other fresh-water formations, abound in fossil *cyprides*, which sometimes constitute entire seams or laminæ, that alternate with the marl. The seed-vessels of the *chara*, a common plant in our ditches and ponds, also occur in profusion; they were formerly supposed to be shells, and from their peculiar structure received the name of *gyrogonites*, which they still bear, although their real nature has long since been ascertained.* In conclusion,

* See an Essay on the fresh-water marls of Scotland, by Mr. Lyell.

Mr. Lyell observes, "that this tertiary series differs essentially from that of the London and Paris basins. The great development of regular beds of blue limestone and shale, the quality and appearance of the eoal, and the thickness of the compact grey, brown, and blaek argillaceous limestones and sandstones, give them the aspeet of the most aneient of our secondary rocks; and it is only by the peculiar species of fluviatile and lacustrine shells, the seed-vessels of the charæ, &c. that the eomparatively recent date of the whole group is demonstrated."

38. Lacustrine formation of Œningen.—Among the tertiary lacustrine formations on the continent, there is one so much celebrated for its organie remains, that I will offer a few remarks on its peculiar eharacters. Œningen, near Constance, has for centuries been known to contain fossil remains of great beauty and interest. A short, but graphic, memoir by Mr. Murchison,* presents in a few pages the history of this aneient lake. The Rhine, in its course from Constance to Sehaffhausen, flows through a depression of the tertiary marine formation, known by the name of *Molassc*, whieh forms hills on both sides of the river, of from 700 to 900 feet in height. In a depression or basin of this molasse, is a series of strata composed of *marls*, and cream-coloured, fine-grained, fetid limestone, with laminated white marl-stone, forming a total

* On a fossil Fox found at Œningen, by R. I. Murchison, Esq., Pres. G.S. &c. Geological Transactions, 1832.

thickness of thirty or forty feet. In the marl-stone, leaves and stems of plants, insects, shells, crustacea, fishes, turtles, a large aquatic salamander, birds, and a perfect skeleton of a fox, have been discovered. The fox was obtained by Mr. Murchison, for whom I developed it, and removed the stone so as to expose the entire skeleton: this extraordinary fossil, which does not differ in its osteology from the recent species, is figured and described in the Geological Transactions for 1832. A tortoise, three feet in length, with the head, neck, tail, and three of the paws, well preserved, has since been discovered. Mr. Murchison concludes that these fresh-water deposits are the contents of a lake, belonging to the newer pliocene epoch, but that the period of their formation must have long preceded the present condition of the country, the Rhine having subsequently worn a channel through them to the depth of several hundred feet.

39. Fossil fishes of Monte Bolca.—I will here notice another interesting assemblage of tertiary strata—the celebrated ichthyolite quarries of Monte Bolca—and then proceed to the consideration of the effects of volcanic action during the geological epochs embraced in this discourse. Monte Bolca is situated on the borders of the Veronese territory, about fifty miles NN.W. of the lagunes of Venice, and forms part of a range of hills of moderate elevation; volcanic deposits abound in the neighbouring Vicentin, and the summit of the

hill is eapped with basalt.* It is prineipally composed of argillaeeous and ealcareous strata, with beds of a cream-eoloured fissile limestone, which readily separates into laminæ of moderate thiekness, and abounds in fishes in the most beautiful state of preservation. They are all eompressed flat, but the seales, bones, and fins remain ; their colour is a deep brown, thus admirably contrasting with the limestone in which they are imbedded. Several hundred distinct speeies are supposed to be contained in these quarries, and thousands of speeimens have been collected ; aecording to M. Agassiz, all the species, though related to the reeent, are extinet. From the immense quantities which oceur in so limited an area, it seems probable that the limestone in which they are imbedded was erupted into the ocean in a fluid state by volcanie ageney ; and that the fishes were thus suffoeated, and surrounded by the ealeareous mass. Nor is this hypothesis without support, for on the appearanee of a volcanic island in the Mediterranean, a few years sinee, hundreds of dead fishes were seen putrid and floating in the waters ; and it cannot be doubted that shoals of fishes might at the same time have been enveloped in the voleanic matter at the bottom of the sea, and beeome eompressed and preserved ; when the mud whieh envelopes them is eonsolidated, and the bed of the Mediterranean elevated above the waters,

* Organic Remains of a Former World, vol. iii. p. 247.

these fishes may resemble the ichthyolites of Monte Bolea.*

40. TERTIARY VOLCANOES OF FRANCE.—In the former lecture I alluded to volcanic action as being still in activity, and as having taken place in more ancient periods; and we have abundant proof that during the immense lapse of time comprehended between the earliest and the latest of the tertiary formations, the internal fires of our globe were not dormant. I have already had occasion to observe, how rarely the former geographical relations of a country are preserved, and that although we may be able to pronounce with certainty that this spot was once dry land,—that there flowed a river,—that here is the bed of an ancient sea—yet we can seldom ascribe limits to the one, or trace the boundaries of the other. But there is one remarkable exception — a district, where the most important and striking geological mutations have taken place, and yet the area of those changes still preserves its ancient physical geography — that district is Auvergne, a province in central France.

Nearly a century since, two French academicians, MM. Guettard and Malesherbes, on their return from an exploration of Vesuvius, arrived at Montelimart, a small town on the left banks of the Rhone, where Faujas St. Fond, a distinguished naturalist, was sojourning. These savans were struck with

* See Lecture VIII.

the pavements of the streets, which were formed of short joints of basaltic columns, placed perpendicularly in the ground; and upon inquiry they found, that the stones were brought from the neighbouring mountains of the Vivarais. This information induced them to survey the country; and upon arriving at Clermont, a town with about 30,000 inhabitants, the capital of Auvergne, they were satisfied that the whole region was of volcanic origin; for in the vicinity of the town they discovered currents of lava, black and rugged as those of Italy, descending uninterruptedly from some conical hills of scoriæ, which still preserved the form of craters. "To those who now visit central France, and see on all sides the most unequivocal marks of volcanic agency — the numerous hills formed entirely of loose cinders, and porous and diversified as if just thrown from a furnace, surrounded by plains of black rugged lava, on which even the lichen almost refuses to vegetate,—it appears scarcely credible, that previous to the last half century, no one had thought of attributing these marks of desolation to the only powers in nature capable of producing them. This, however, is perfectly natural, and not without examples. The inhabitants of Herculaneum and Pompeii built their houses with the lava of Vesuvius, ploughed up its scoriæ and ashes, and ascended its crater, without dreaming of their neighbourhood to a volcano which was to give the first proof of its energies by burying them beneath its eruptions, The Catanians regarded as a fable all mention of the former activity of Etna, when, in 1669, half their town was overwhelmed by its lava currents."*

41. Extinct volcanoes of Auvergne.—The country which is the site of the extinct volcanoes to which I am about to call your attention, may be described as a vast plain, situated in the department of the Limagne d'Auvergne: it is so remarkable for its fertility, that it is called the Garden of France; a quality attributable to the detritus of volcanic rocks, which enters into the composition of the soil. It is inclosed on the east and west by two parallel ranges of gneiss and granite. Its average breadth is twenty miles, its length between forty and fifty, and its altitude about 1,200 feet above the level of the sea. The surface of this plain is formed of alluvial deposits, composed of granitic and basaltic pebbles, and boulders, reposing on a substratum of limestone. Hills, of various elevations, composed of calcareous rocks, are scattered over the plain; and the river Allier flows through the district, over beds of limestone or sandstone, except where it has excavated a channel to

* Geology of Central France, by G. Poulett Scrope, Esq. F.R.S., 1827. Mr. Bakewell was the first English geologist who directed attention to this remarkable district; (Travels in the Tarentaise, by Robert Bakewell, Esq. 2 vols. 8vo. 1823;) subsequently Dr. Daubeny, Messrs. Scrope, Lyell, and Murchison, have severally published highly interesting treatises on the subject.

the foundation-rock of granite. The hills composed of calcareous alluvial deposits are the remains of a series of beds, which once constituted an ancient plain, at a higher elevation than the present. Many are surmounted by a crest or capping of basalt, to which their preservation is probably attributable; others have escaped destruction from being protected by horizontal layers of a durable limestone, which I shall presently describe. We have, then, as the ground plan of the district, an extensive plain, chequered with low hills of fresh-water limestone, which are capped with compact lava (Plate VIII. figs. III. IV.); the boundaries of the plain being formed of ranges of primary rocks, 3,000 feet in altitude. To the westward the limestone disappears, and a plateau of granite rises to a height of about 1,600 feet above the valley of Clermont, being 3,000 feet above the level of the sea. This supports a chain of volcanic cones and dome-shaped mountains, about seventy in number, varying in altitude from 500 to 1,000 feet from above their bases, and forming an irregular range nearly twenty miles in length, and two in breadth. The highest point of this range is the Puy de Dome, which is 4,000 feet above the level of the sea (Plate VIII. fig. II. 4), and is composed entirely of volcanic matter; it possesses a regular crater, 300 feet deep, and nearly 1,000 feet in circumference. Many of these cones retain the form of well-defined craters, and their lava currents may be traced as readily as those of Vesuvius.

42. Crater of Puy de Come.—One of the most remarkable cones is the Puy de Come, which rises from the plain to the height of 900 feet; its sides are covered with trees, and its summits present two distinct craters, one of which is 250 feet in depth. A stream of lava may be seen to have issued out from the base of the mountain, which at a short distance, from having been obstructed by a mass of granite, has separated into two branches; these can be traced along the granitic platforms, and down the side of a hill into an adjacent valley, where they have dispossessed a river of its bed, and constrained it to work out a fresh channel between the lava and the granite of the opposite bank. Another cone rises to the height of 1,000 feet above the plain, having a crater nearly 600 feet in vertical depth, and a lava current, which first falls down a steep declivity, and then rolls over the plain in hilly waves of black and scorified rocks. In one part of this volcanic group is a circular system of cones, apparently the produce of several rapidly succeeding eruptions. "The extraordinary character of this scene impresses it for ever on the memory; for there is, perhaps, no spot, even among the Phlegræan fields of Italy, which more strikingly displays the characters of volcanic desolation. Although the cones are partially covered with wood and herbage, yet the sides of many are still naked;

and the interior of their broken craters, rugged, black, and scorified, as well as the rocky floods of lava with which they have loaded the plain, have a freshness of aspect, such as the products of fire alone could have so long preserved, and offer a striking picture of the operation of this element in all its most terrible energy."* A description of the accompanying sketches† will serve to illustrate these remarks.

Plate VIII. fig. III. The environs of Clermont. The town is seen on the plain or basin, which has been excavated by diluvial agency, since the deposition of the strata which form the surrounding hills. In front is a basaltic peak (*coloured green*), crowned by the Castle of Montrognon; and beyond are basaltic platforms on hills of limestone. In the distance is the primary escarpment, forming part of the boundary of the volcanic district.

Plate VIII. fig. II. Part of the southern volcanic chain of Puys, exhibiting the broken craters of Chaumont; from the bases of several, lava currents are seen to have issued. No. 1, Montchal; 2, Puys de Montgy; 3, Monjughat; 4, Mont Dome in the distance.

Plate VIII. fig. IV. represents hills of secondary Jura limestone, capped by basalt (*coloured green*). These crests are the terminations of lava currents,

* Scrope's Geology of Central France.

† The delineations are reduced from the elaborate and beautiful drawings of Mr. Scrope.

that once extended over the whole area, covering a platform of primary rocks, and flowing on to the secondary strata, which, in this part of Ardèche, constitute an elevated limestone district.

This region affords a striking illustration of the erosion of the surface of a country by alluvial action. The thickness of the volcanic mass is between 300 and 400 feet; it is composed of two distinct beds of basalt, separated by a layer of scoriæ and volcanic fragments. Many portions, both of the upper and lower beds, are made up of well-defined, vertical, polygonal columns. The streams of lava to which these plateaux belong, have been traced for more than thirty miles; they rise in a narrow ridge across the primitive heights, and then spread over, and lie conformably upon, the secondary formations. The limestone beneath the basalt is, in some places, covered with vegetable soil, containing a common species of terrestrial shell (*Cyclostoma elegans*). The nearly horizontal disposition of the basalt, its columnar structure, and position on the limestone, into which it has injected veins and dikes, render it, as Mr. Scrope observes, very analogous to the ancient volcanic rocks of Ireland, which will be described in a future lecture.

43. Mont Dor.—Before entering upon the description of the organic remains found in the rocks and strata we have thus hastily surveyed, it will be necessary to notice another system of extinct

volcanoes, situated in the same province, and connected with the Puy de Dome. While in the district I have just described, the primitive soil is only partially obscured by the volcanic products, in Mont Dor, the granitic foundation is covered over an area of many miles in extent, and the erupted masses attain a considerable elevation. Mont Dor is a mountainous tract, the highest portion of which is about 6,000 feet in altitude. It consists of a group of seven or eight rocky summits, which form a zone a mile in diameter, the whole consisting of a succession of beds of volcanic origin. It is deeply channelled by two principal valleys, and furrowed by many minor water-courses, all originating near the central eminence, and diverging towards every point of the horizon. The beds of which this group is composed, consist of scoriæ, pumice-stone, trachyte, and basalt; these rocks dip off from the central axis, and lie parallel to the sloping flanks of the mountain, as is the case in Etna, the Peak of Teneriffe, and all other insulated volcanic mountains (see the section of a volcano, Plate VIII. fig. 1). There is no crater, all vestiges having been destroyed since the extinction of its fires; but streams of lava may be traced in elevated peaks, over a gorge which occupies the very heart of the mountain, and they extend to a distance of many miles. A remarkable natural section, worn by a cascade, at a short distance from the baths of Mont Dor, exhibits the general structure of the beds (Pl. VIII. fig. 5). They consist in a descending series of—1. Porphyritic trachyte; a volcanic rock, 160 feet in thickness. 2. Arenaceous tufa. 3. Columnar basalt. 4. Breccia, made up of volcanic fragments, cemented together by tufa. 5. Thick beds of basalt. 6. White ferruginous tufa, enveloping fragments of granite, basalt, &c. This bed is traversed by veins of the overlying basalt.

I may add, that the volcanic vents of central France are evidently of very different ages; some being of immense antiquity, while others must be of comparatively recent origin, for they have exploded through the older beds of basalt.

44. Fresh-water limestone, and organic remains of Auvergne.—The volcanic rocks of this district present alternations of limestone, abounding in fresh-water shells and other animal remains; with basalt, scoriæ, and other igneous productions, based on a foundation of granite. These beds are arranged in the following order, beginning with the lowest or most ancient:—

1st. Clay, sand, and breccia, without organic remains.

2d. Limestone and calcareous marl, in strata nearly horizontal; about 900 feet thick. These are entirely of fresh-water origin, and abound in shells of the genera *potamides*, *helix*, *planorbis*, and *lymnea*, which are known to inhabit lakes and rivers. Some of the beds contain bitumen; others are entirely made up of the cases of the caddis-worm (*Indusia tubulata*), cemented together by calcareo-silicious matter. This specimen, which was in the cabinet of Faujas St. Fond, displays the characters of this remarkable concrete: it consists of the tubes or cases of the larva of a species of *phryganea;* similar remains have been mentioned as occurring in abundance in the alluvial silt of Lewes Levels (page 45). The tubes are formed by the adhesion of shells to the outer surface of the silken case secreted by the insect; these cases are abandoned by the animal when its metamorphosis is completed, and groups of them may be seen in ditches or lakes. In the fossil they have been cemented by calcareous infiltration into a stone, so hard as to be employed for building. The attached shells are so minute, that more than a hundred are affixed to one tube, and the space of a cubic inch often includes ten or twelve tubes. If, says Mr. Scrope, we consider that repeated strata, of five or six feet in thickness, almost entirely composed of these tubes, once extended over the whole plain of the Limagne, occupying a surface of many hundred square miles, we may have some idea of the countless myriads of minute beings which lived and died within the bosom of that ancient lake. In the limestone, associated with land and fresh-water shells, and remains of vegetables, are bones of the palæotherium, anoplotherium, lagomys, martin, dog, rat, tortoise, crocodile, serpent, and birds, and in which the lava currents that have flowed over them have produced but little change. This series comprises also beds of gypseous and laminated marls, with intercalations of silicious limestone, containing impressions of lake and river shells. In some localities, the fresh-water limestone has an intermixture of volcanic matter, presenting all the characters of a sediment slowly and tranquilly deposited in a lake, into which ashes, and fragments of rocks and scoriæ, were projected by a neighbouring volcano; while there are beds which appear to have been formed by a violent intrusion of volcanic matter.

3d. Immense beds of volcanic production, consisting of basalt, scoriæ, &c. now existing in sheets of lava, either spread over the tabular masses of fresh-water limestone, or appearing as crests on the summits of the lower hills. (Plate VIII. fig. 3.)

4th. Sand and diluvial gravel, containing bones of the mastodon, elephant, hippopotamus, rhinoceros, tapir, horse, boar, felis, hyena, bear, dog, beaver, hare, &c.; with these are associated lignite, and other vegetable remains. Some of the beds of limestone abound in seed-vessels of the chara; and the laminated clays contain fishes, and leaves, stems, &c. of reeds and other plants.

There are several incrusting springs in Auvergne, largely impregnated with carbonic acid, which pour out immense quantities of calcareous tufa; these burst through the primary rocks, which form the base of the whole territory, and cover the volcanic focus whence these mineral waters, in all probability, originate. Thermal springs are also very numerous throughout this district.

45. Summary of the geological phenomena of Auvergne.—In the calcareous and siliceous limestones of Auvergne, and their associated laminated marls, gypsum, lignite, and conglomerate, we have a general analogy with the older fresh-water tertiary formations of Paris and the Isle of Wight; the shells and plants being similar, and the quadrupeds of the same genera. And if we suppose the Paris basin to have been elevated during the active state of neighbouring volcanoes, and that successive streams of lava had flowed over its sedimentary deposits, we should have a series of phenomena resembling those of Auvergne, with the exception that the presence of marine remains would denote that the basin had been filled with salt water. The facts submitted to our notice appear to establish the following sequence of physical events.

1st. The elevation, after the deposition of the secondary limestone, of the whole area of the primary rocks which form the foundation of central France.

2dly. A period of tranquillity, during which fresh-water lakes occupied the irregular hollows of the district; the neighbouring country being inhabited by palæotheria, anoplotheria, and other extinct mammalia, whose bones, together with the then existing vegetation, and the shells of the lacustrine mollusca, were enveloped in the tranquil depositions going on in the lacustrine basins.

3dly. Another elevation of the district; a new system of lakes was established, the country became clothed with forests, and inhabited by large deer, oxen, rhinoceroses, and hyenas, whose skeletons were imbedded in the sediments of the waters.

4thly. The volcanoes became active; explosions took place through hundreds of vents; trachyte and basalt were ejected, and in some places pierced the fresh-water deposits, while in others they overspread them with sheets of lava. Vegetation still flourished, and the remains of plants were entombed in the volcanic products.

5thly. Another period of tranquillity—the rivers, and other water-courses, dammed up, or deranged by the lava currents, formed new channels, and accumulated beds of gravel, sand, and clay. Gigantic deer and oxen still inhabited the district, having for contemporaries hyenas and other carnivora. Volcanic eruptions succeeded, and continued till a comparatively recent period.

Lastly. Floods and rivers of later date, which now constitute the drainage of the country, began to wear away channels through the beds of lava and limestone to the granite rock beneath, intersected the country with valleys and ravines, and spread over the ancient beds the modern alluvial soil.*

* This account of the volcanic district of Auvergne, is an abstract of the interesting Essays of Messrs. Bakewell, Scrope,

46. Erosion of valleys by water-currents. —There is perhaps no district which exhibits in more striking characters the erosive power of running water, than Auvergne. In many plaees the basalt is columnar, like that of Staffa, and the Giants' Causeway; and one range, on the banks of the Ardêehe, forms a majestie eolonnade 150 feet in height, extending a mile and a half along the valley which has been channelled out by the stream that flows at its base. Mr. Scrope's deseription of this process is highly graphie. "The bed of the Ardêehe is strewed with basaltic boulders, pebbles, and sand, originating from the destruction of the columnar ranges. In some of the volcanie cones the beds of basalt may be traeed issuing from the crater and following the inequalities of the valley, just as a stream of lava would flow down the same course at the present time. Yet these ancient eurrents have since been corroded by rivers which have worn through a mass of rock 150 feet in height, and formed a ehannel even in the granite rocks beneath, since the lava first flowed into the valley. In another spot, a bed of basalt 160 feet high, has been eut through by a mountain stream, and very beautiful columnar masses are displayed. The vast excavations effected by the erosive power of water along the valleys which feed the Ardêehe, sinee

Lyell, Murchison, Dr. Daubeny, Dr. Hibbert, MM. Croiset, Jobert, Robert, and Bertrand-Roux. Mr. Scrope's work eannot be perused, even by the general reader, without deep interest.

their invasion by lava currents, prove that even the most recent of these volcanic eruptions belong to an era incalculably remote."

47. Extinct volcanoes of the Rhine.— I have dwelt so long on the Phlegræan fields of Auvergne, that but a brief space can be afforded to another group of tertiary volcanoes. Every one who has ascended the Rhine, will remember where

> "The castled crag of Drachenfels
> Frowns o'er the wide and winding Rhine,"

forming one of the Siebengebirge, or Seven Mountains, whose majestic and graceful forms suddenly

Tab. 46.—The Drachenfels.

(*Drawn by Miss Jane Allnutt.*)

burst on the sight, rising from the level plains on the right bank of the river, to an altitude of nearly

1,500 feet. These picturesque objects belong to a group of extinct volcanoes; while, on the opposite side of the river, the Eifel, with its crater covered with scoriæ and cinders, and lava currents still distinctly visible, attest the wide area over which those ancient fires once extended. Unlike the district we have just noticed, the foundation rock of the country is an ancient sedimentary deposit, called *greywacke*, consisting of coarse red sandstone and slate of a peculiar character, which we shall describe hereafter, thrown into a highly inclined position. Through these beds the volcanic eruptions, consisting of trachyte, basalt, and other modifications of trap rocks and scoriæ, have forced their way. The basalt is black, very compact, and breaks into sharp fragments; it is frequently columnar, and the separate hexagonal pillars are made use of for posts and paving, in the adjacent towns. Such, says Mr. Horner (whose interesting memoir* has furnished the materials for this imperfect sketch), is the profusion of basaltic pillars, that the walls of the town of Linz are wholly built of these materials, placed on their sides, with the ends projecting outwards. The streets are paved with the smaller columns set on end, thus forming a miniature representation of the Giants' Causeway; and the same volcanic product forms a large proportion of the walls of Bonn and Cologne. The greywacke is

* On the Geology of the Environs of Bonn, by Leonard Horner, Esq. F.R.S. Geological Transactions, vol. iv. 1836.

covered by a series of tertiary deposits, consisting of sand, sandstone, clay, and lignite, constituting what is termed a *brown coal formation*. On these strata an extensive layer of gravel is superposed, over which is spread a loosely coherent, sandy loam, provincially termed *loess*, which contains recent species of terrestrial and fresh-water shells, and forms the subsoil of the vast plains in which Bonn and Coblentz are situated, extending as far as the falls of Schaffhausen.

48. Brown coal formation.—As the usual condition in which bituminized vegetable matter occurs in the tertiary formations, is well exemplified in the brown coal, or lignite, of the Rhine, it will be instructive to examine the characters of this deposit somewhat in detail; for we shall thereby obtain data which will prepare us for the investigation of the ancient carboniferous system. This formation, which is spread over a great extent of country on both sides of the Rhine, consists of clay, sand, sandstone, conglomerates, clay and iron-stone, and lignite, or bituminized wood of various qualities, disposed in distinct beds, and intermixed with argillaceous matter. The breadth of the ridge of low hills formed by this assemblage of strata on the left bank of the Rhine, is from three to five miles, its elevation varying from 50 to 200 feet.

The lignite occurs in the following states:—1. A black earthy and pulverulent substance. 2. Concretionary masses, with leaves and fragments of wood. 3. Wood in various degrees of bituminization, and of shades of colour, from a light-brown to jet-black. 4. Very finely laminated masses of bituminous matter and clay, of a dark chocolate colour, and separating into elastic flakes, as thin as paper, whence its name *papierkohle*. These specimens, collected by Sir P. M. de Grey Egerton, Bart. exhibit the peculiar character of the substance, which is so highly bituminous as to burn with a bright flame. The wood is generally in inconsiderable fragments; but stems of large trees, somewhat compressed, occasionally occur; in some instances the trees are imbedded in an upright position, with the roots attached and the stems passing through several beds of lignite. In many examples the wood is so little changed, that, like the timber of our peat-bogs, it is employed in building; in others it is highly pyritous, or in other words, is impregnated with sulphuret of iron, like the fossil vegetables of Sheppey. Mr. Horner states, as the result of his investigations, that there were extensive fresh-water lakes, in the sediments of which trees and plants, drifted by land-floods, were engulfed; and that volcanic eruptions were simultaneously going on, in the same manner as in the modern submarine volcanoes. There is a great fault, or dislocation, of the brown coal formation, which may be attributed to a powerful and sudden volcanic explosion, that probably occasioned the elevation of the

Siebengebirge, and raised up that portion of the coal-beds which reposes on the flanks of those peaks. The gravel covering the lignite, must have been strewed over the plain previously to this elevation, for it is found on both sides of the river at a great height, and not in the intermediate plain. These inductions are so evident as to require no comment.

The ancient alluvium, the *loess*, very much resembles a bed of loam which occurs in some parts of Lewes Levels, and incloses fresh-water and land shells of many existing species; it rarely contains bones of quadrupeds; a few remains of the horse and mammoth have however been discovered.* From the extensive distribution of this deposit, and its occurrence at various elevations, in some instances on the flanks of mountains 1,200 feet above the level of the sea, at others spread out over the gravel of the vast plain of the Rhine, it is inferred, that although the *loess* has been deposited since the existing system of the hills and valleys of the country, yet that changes must have taken place in the physical geography of the district, subsequent to its original formation; and there is reason to conclude, that since the deposition of this fluviatile loam all the land between Switzerland and Holland has suffered a subsidence, and a subsequent elevation, to the amount of many hundred feet.†

* Principles of Geology, vol. iv. p. 33.

† Ibid.; read with particular attention, pp. 36 and 37.

49. OTHER TERTIARY STRATA OF EUROPE, NORTH AMERICA, &c.—It has already been mentioned that strata, referable to the period comprehended between the newest secondary formations and the human epoch, occur throughout Europe, presenting in some instances well-defined groups, with marked boundaries; in others, vast areas, over which these deposits are irregularly spread. The geographical relations of the tertiary strata to the existing lands and seas, is an interesting subject of inquiry, but one on which my limits forbid me to enter. I may however observe, that Europe must have possessed many of its most striking physical characters at the commencement of the eocene period; and that its present configuration has been produced by the conjoint effect of successive mutations in the relative level of land and water, during the deposition of the marine and fresh-water strata, reviewed in this discourse. In India, formations of a like nature have been observed in the Burmese empire, in the Sub-Himalaya mountains, and in the Caribari hills; and among the remains of various quadrupeds a new species of anthracotherium, one of the genera discovered in the tertiary strata of France, has been found.

In North America the researches of Dr. Morton, Professor Vanuxem, and other observers, have shown that in the territories of the United States tertiary deposits extend over a great part of Maryland, along the coast of New York and New

England, and occur in New Jersey, Delaware, Long Island, &c. The tertiary beds of Maryland consist of limestone, clay, sand, and gravel, and abound in the usual types of European tertiary marine shells. I have placed before you an extensive collection from the United States, for which I am indebted to the kindness of Dr. Morton, Mr. Conrad, Professor Silliman, Dr. Harlan, and other American *savans;* and you will observe how striking is the general analogy between these shells and those of the Paris and London basins. The *turritella, venericardia, fusus, ancilla,* &c. are identical with the European species; but some of the types are altogether new.

50. Altered tertiary strata of the Andes. —But striking as are the proofs already adduced of elevation, and other effects of volcanic agency during the tertiary period, these sink into comparative insignificance when contrasted with the enormous changes which have taken place in the great mountain chains of South America during the same geological epoch. From the researches of an eminent naturalist and highly intelligent observer, Mr. Charles Darwin, we learn that an extensive tertiary system, analogous to that of Europe, skirts both flanks of the primary rocks which form the southern chain of the Andes, the latter having suffered a certain degree of elevation before the deposition of the former. These strata are of great thickness and extent, and separable

into two groups; the lowermost beds, like those of Auvergne, repeatedly alternate with lavas, and thus denote the commencement of the eruptions of the ancient craters. Over these are accumulations of porphyritic pebbles, covered, at elevations of many hundred feet, by beds of shells of recent species; and the sides of the mountains appear like a succession of sea-beaches, which have been slowly and tranquilly lifted up. The altered character of the tertiary deposits within the influence of the igneous products,—the transmutation of accumulations of loose pebbles into solid, compact rocks,—and the occurrence of metalliferous veins in strata of comparatively modern formation,—are facts so powerfully exemplifying the geological principles enunciated in the former lectures, that although this discourse has extended to a great length, I cannot omit Mr. Darwin's spirited and graphic description of these phenomena, as originally communicated in a letter to Professor Henslow, of Cambridge, dated Valparaiso, March 1835.

"You will have heard of the dreadful earthquake of the 20th February. I wish some of the geologists, who think the earthquakes of these times are trifling, could see how the solid rocks are shivered. In the town there is not one house habitable; the ruins remind me of the drawings of the desolated eastern cities. We were at Valdivia at the time, and felt the shock very severely. The sensation was like that of skating over very thin ice, that is, distinct undulations were perceptible. The whole scene of Conception and Talesana is one of the most interesting spectacles we have beheld since we left England. I was much pleased at Chiloe by finding a *thick bed of recent oyster-shells* *capping the tertiary plain,* out of which grew large forest trees. I can prove that both sides of the Andes have risen in this recent period to a considerable height. Here the shells were 350 feet above the sea. On the bare sides of the Cordilleras complicated dykes and wedges of variously coloured rocks are seen traversing, in every possible form and shape, the same formation, and thus proving by their intersections a succession of violences. The stratification in all the mountains is beautifully distinct, and owing to a variety of colouring can be seen at great distances. Porphyritic conglomerates, resting on granite, form the principal masses. I cannot imagine any part of the world presenting a more extraordinary scene of the breaking up of the crust of the globe than these central peaks of the Andes. The strata in the highest pinnacles are almost universally inclined at an angle from 70° to 80°. I cannot tell you how much I enjoyed some of the views; it is alone worth coming from England to feel at once such intense delight. At an elevation of from ten to twelve thousand feet there is a transparency in the air, and a confusion of distances, and a stillness, which give the sensation of being in another world. The most important and most developed formation in Chili is the porphyritic concrete. From a great number of sections I find it to be a true coarse conglomerate or breccia, which passes by every step in slow gradation to a fine clay-stone porphyry; *the pebbles and cement becoming porphyritic, till at last all is blended in one compact rock.* The porphyries are excessively abundant in this chain, and at least four-fifths of them, I am sure, *have been thus produced from sedimentary beds in situ.* The Uspellata range is geologicallly although only six or seven thousand feet high, a continuation of the grand eastern chain. It has its nucleus of granite, consisting of beds of various crystalline rocks, (which I have no doubt are subaqueous lavas,) alternating with sandstone, conglomerates, and white aluminous beds, like decomposed felspar, with many other curious varieties of sedimentary deposits. In an escarpment of compact greenish sandstone, *I found a small wood of petrified trees in a vertical position,* or rather the strata were inclined about 20° or 30° to one point of the trees, and 70° to the other; that is, before the tilt, they were truly vertical. The sandstone consists of many horizontal layers. Eleven of the trees are perfectly silicified, and resemble the dicotyledonous wood which I found at Chiloe and Conception; the others, from thirty to forty in number, I only know to be trees from the analogy of form and position; they consist of snow-white columns of coarsely crystallized carbonate of lime. The largest trunk is seven feet in circumference. They are all close together, within one hundred yards, and about the same level; no where else could I find any. It cannot be doubted that the layers of fine sandstone have quietly been deposited between a clump of trees, which were fixed by their roots. *The sandstone rests on lava; is covered by a great bed, apparently about one thousand feet thick, of black augite lava; and over this there are at least five grand alternations of such rocks, and aqueous sedimentary deposits, amounting in thickness to several thousand feet.* According to my view of these phenomena, the granite, which forms peaks of a height probably of 14,000 feet, has been fluid in the tertiary epoch; strata of that period have been altered by its heat, and are traversed by dykes from the mass, and are now inclined at high angles, and form regular or complicated anticlinal lines. *To complete the climax, these same sedimentary strata and lavas are traversed by very numerous true metallic veins of iron, copper, arsenic, silver, and gold, and these can be traced to the underlying granite. A gold mine has been worked close to the clump of silicified trees!*"

51. TERTIARY SALIFEROUS DEPOSIT.—Not only coal, but even extensive beds of rock salt occur in the tertiary system. The celebrated salt mines of Gallicia, of which M. Boué* has given an interesting description, belong to this epoch. The deposit is nearly 3000 yards long, 1066 broad, and 280 yards deep. The upper part of the mine

* Journal de Géologie.

consists of green salt, with nodules of gypsum in marl. The salt contains in some places lignite, bituminous wood, and shells. In the lower division are beds of arenaceous marls, with lignite, impressions of plants, and veins of salt; coarse sandstone, with vegetable remains; aluminous and gypseous shale, and indurated calcareous marl, with sulphur, salt, and gypsum.

52. Retrospect.—So numerous and varied have been the phenomena presented to our notice, that a comprehensive retrospect is necessary, in order that we may obtain a correct idea of the important and highly interesting deductions resulting from this general survey of the tertiary formations.

In the pliocene, or newer tertiary, which also embraces the mammalian epoch of the last lecture, the fossil remains in the alluvial deposits afford incontestible proof that the mammoth, mastodon, hippopotamus, dinotherium, and other colossal animals of extinct species and genera, together with birds, reptiles, and enormous carnivora, inhabited such districts of our continents as were then dry land; while the older tertiary, or eocene, incloses the bones of land animals, principally of a lacustrine character, which approximate to certain races that now exist in the torrid zone, but belong to extinct genera, that preceded the mammoth and the mastodon. The seas and lakes of that remote epoch occupied areas which are now above the waters; and rocks and mountains, hills and valleys, streams and rivers, diversified the surface of countries which are now destroyed or entirely changed; and whose past existence is revealed by the spoils which the streams and rivers have accumulated in the ancient lakes and deltas. The ocean abounded in mollusca, crustacea, and fishes, a large proportion of which is referable to extinct species. Crocodiles, turtles, birds, and insects, were contemporary with the palæotherium, and anthracotherium; and animal organization, however varied in certain types, presented the same general outline as in modern times; the extinction of species and genera being then, as now, in constant activity. The vegetable world also contained the same great divisions; there were forests of oak, elm, and beech; of firs, pines, and other coniferous trees; palms, tree-ferns, and the principal groups of modern floras; while the water, both salt and fresh, teemed with the few and simple forms of vegetable structure peculiar to that element. The state of the inorganic world is not less manifest: the abrasion of the land by streams and rivers,—the destruction of the sea-shores by the waves, and the formation of beach and shingle,—the desolation inflicted by volcanic eruptions,—all these operations were then, as now, in constant action. The bed of an ancient sea, containing myriads of the remains of fishes, crustacea, and shells, now forms the site of the capital of Great Britain; and accumulations of tropical fruits and plants, drifted by ancient currents from other climes, constitute islands in the estuary of the Thames; while the sediments of lakes and gulfs, teeming with the skeletons of beings which are blotted out from the face of the earth, compose the soil of the metropolis of France.

Although the changes in the relative level of the land and sea during this epoch were numerous and extensive, yet one region still preserves traces of its original physical geography; and although the earthquake has rent its mountains to their very centre—though hundreds of volcanoes have again and again spread desolation over the land—and inundations and mountain torrents have excavated valleys, and chequered the plains with ravines and water-courses—yet the grand primeval features of that country remain; and we can trace the boundaries of its ancient lakes, and the succession of changes it has undergone from the first outbreak of its volcanoes, to the commencement of the present state of repose. The lowermost lacustrine deposits in Auvergne, which are spread over the foundation rock of granite unmixed with igneous productions, mark the period antecedent to the volcanic era; while the intrusions of lava and scoriæ in the superincumbent strata, denote the first eruptions of Mont Dome. The succeeding period of tranquillity is recorded in characters alike intelligible. The slow deposition of calcareous mud—the incrustation of successive generations of aquatic insects, crustacea, and mollusca, and we may even add of infusoria—

the imbedding of the bones of mammalia, birds, and reptiles—the accumulation of lignite and other vegetable matter—are data from which we may restore the ancient country of Central France.

It was a region encircled by a chain of granite mountains, watered by numerous streams and rivulets, and possessing lakes of vast extent. Its soil was covered with luxuriant vegetation, and peopled by palæotheria, anoplotheria, and other terrestrial mammalia; the crocodile and turtle found shelter in its marshes and rivers; aquatic birds frequented its fens, and sported over the surface of its lakes; while myriads of insects swarmed in the air, and passed through their wonderful metamorphoses in the waters. In a neighbouring region,* herds of ruminants and other herbivora, of species and genera now no more, with birds and reptiles, were the undisturbed occupants of a country abounding in palms and tree-ferns, and having rivers and lakes, with gulfs which teemed with the inhabitants of the sea; and to this district the fiery torrents of the volcano did not extend. But to return to Auvergne —a change came over the scene—violent eruptions burst forth from craters long silent—the whole country was laid desolate—its living population was swept away—all was one vast waste, and sterility succeeded to the former luxuriance of life and beauty. Ages rolled by—the mists of the mountains and the rains, produced new springs, torrents, and

* The Paris basin is about 220 miles from Auvergne.

rivers—a fertile soil gradually accumulated over the cooled lava currents and the beds of scoriæ, to which the sediments of the ancient lakes, borne down by the streams, largely contributed. Another vegetation sprang up—the mammoth and mastodon, with enormous deer and oxen, now quietly browsed in the verdant plains—other changes succeeded—those colossal forms of life in their turn passed away, and at length the earlier races of mankind took possession of a country, which had once more become a scene of fertility and repose.

To those who have favoured me with their attention through these discourses, it cannot be necessary to insist that the changes in organic and inanimate nature, which I have thus rapidly portrayed, are supported by proofs so incontrovertible, and traced in language so intelligible, as to constitute a body of evidence with which no human testimony can compete. It is true that the time required for this succession of events must have extended over an immense period; but, as I have before remarked, time and change are great only in relation to the beings which note them, and every step we take in geology shows the folly and presumption of attempting to measure the operations of nature by our own brief span. "There are no minds," says Mr. Scrope, "that would for one moment doubt that the God of Nature has existed *from all eternity;* but there are many who would reject as preposterous, the idea of tracing back the history of *His works* a million of years. Yet what is a million, or a million of millions of years, when compared to eternity?" *

Germany presents us with an interesting series of analogous changes, effected in a later era. The outburst of the now extinct volcanoes of the Rhine, the accumulation of fluviatile silt over the plains, and the subsequent elevation of the whole country, show that these physical mutations were not confined to a single region or period.

In the Andes, the enormous disruptions and elevations of the most ancient as well as modern deposits, teach us, that through a long lapse of ages, the volcanic fires of South America have acted with intense energy; and yet more, that the melting and transmutation of loose materials into compact rocks, the conversion of incoherent strata into solid stone, and even the sublimation of gold and other metals into fissures and veins, are phenomena which have taken place since our seas were peopled by mollusca of existing species. The importance of these extraordinary and interesting facts will be rendered more obvious in a subsequent lecture.

53. Concluding remarks.—In conclusion, it will be useful to inquire, even though some repetition may be incurred, what are the legitimate inferences from the facts that have been placed before us, as to the condition of the earth and its inhabitants during the tertiary epoch? Was there, as some have supposed, an essential difference in

* Geology of Central France.

the constitution of the earth?—was its surface more covered with lakes and marshes than now?—and did animal life more abound in those types, which are suitable to a lacustrine condition?—or have such conclusions been drawn from a partial view of the phenomena, and do the facts only warrant the inference that certain regions which are now dry land were in ancient times occupied by vast lakes, and that there may have existed contemporaneously as great an extent of dry land as at present, in areas now buried beneath the ocean? In the fossilized remains of the tertiary population of the land and waters, we find all the grand types of the existing animal creation—terrestrial, lacustrine, and marine mammalia—herbivora, carnivora, birds of every order, and of numerous species and genera—reptiles, fishes, crustacea, insects, zoophytes, and even those living atoms, the infusoria*—in short, all the leading divisions, and even sub-divisions of animal existence. In the vegetable world, as I have already remarked, the same general analogy is maintained. And as all these varied forms of being required physical conditions suitable to their respective organizations, we have at once conclusive evidence that the general constitution of the earth, during the tertiary epoch, could not have essentially differed from the present. Dry land and water, continents

* In tertiary strata the remains of beings of which thousands of millions would occupy but a cubic inch have been discovered. They will be described hereafter.

and islands, existed then, as now,—their geographical distribution may have varied,—the temperature in certain latitudes may have been much higher,—countries may have existed in areas now covered by water, and marshes and fens have prevailed in regions now arid and waste; but the same agents of destruction and of renovation were then, as now, in constant activity. It is true that immense numbers of large mammalia lie buried in regions where it is utterly impossible such creatures could now find subsistence, and in latitudes whose climates are unsuitable to such forms of organization. But some of these apparent anomalies may be explained by the fact, that the alluvial beds in which these remains occur cannot have been the sites of the dry land on which these lost beings existed; they are the sediments of ancient lakes—the deltas of former rivers—the estuaries of seas—they are formed of the detritus of the land transported from a distance. If the Gulf-stream annually strews the shores of the Hebrides with the fruits of torrid climes, the currents of the ancient seas must have produced analogous results; and in our attempt to interpret past changes, it must not be forgotten that they have most probably been produced by causes similar to those which are still in action. I do not question the assumption that the countries containing these fossil remains may have enjoyed a milder climate during the tertiary epoch than at present; or that in still more ancient periods there may not have prevailed all over the world a much higher temperature than now, dependent on the internal condition of our planet. But it appears to me that the variation of climate which a change in the distribution of the land and water would occasion, as suggested by Mr. Lyell,*—and a difference in the radiation of heat from internal sources, as explained by Sir J. Herschel and Mr. Babbage (page 97),—may account for the phenomena which our examination of the tertiary formation has revealed.

The occurrence of groups of animals of the same families, in certain districts, is in strict conformity with the distribution of living species, in regions not under the control of man. Thus when ancient France presented a system of lakes, animals fitted for such physical conditions found there the means of subsistence—when the vast plains and forests of America were adapted for colossal mammalia, there the mastodon and the mammoth obtained food and shelter—and when the former continent of Europe swarmed with herbivora, the carnivorous tribes, as the lion and the tiger, the bear and the hyena, obtained the support which their habits and economy required.

One striking feature in the events that have passed in review before us, is the immense scale on which the extinction of species and genera has been effected: but it must be remembered that our observations have extended over a period of vast

* Principles of Geology, vol. i. chap. vii.

duration, and that we therefore have seen the aggregate effects of a law, which even before our eyes is producing great and important modifications in the system of animated nature.

Thus the tertiary epoch displays to us a state of the globe replete with life and happiness: the physical constitution of the earth's surface being then, as now, admirably adapted to the habits and economy of the beings it was designed to support. In the most ancient periods, forms of life prevailed which gradually became extinct, and were succeeded by others which in their turn also passed away; and if we trace the varying types of being from the earliest ages, we perceive a gradual approach to the present condition of organic existence; the grand line of separation between the present and the past being the creation of the human race. From that period, in proportion as man has extended his dominion over the earth, many races of animals have been either exterminated, or modified by his caprices or necessities; and it cannot be doubted, that in the lapse of a few thousand years, a total change will have been effected by human agency alone, in the geographical distribution and in the relative numerical proportion of the existing genera and species.

# LECTURE IV.

1. Introductory remarks. 2. Secondary formations. 3. The chalk formation. 4. Chalk and flint. 5. Flint nodules. 6. Organic remains in flint. 7. Sulphuret of iron. 8. Mæstricht beds. 9. St. Peter's mountain. 10. Mosæsaurus of Mæstricht. 11. Lower group of the chalk. 12. Organic remains of the chalk. 13. Fossil vegetables. 14. Fossil zoophytes. 15. Radiaria and crinoidea. 16. Echinites. 17. Shells of the chalk. 18. Cephalopoda. 19. The belemnite. 20. The nautilus. 21. The ammonite, or cornu ammonis. 22. Turrilite, hamite, &c. 23. Spirolinites. 24. Infusoria in flint. 25. Crustacea of the chalk. 26. Fishes of the chalk—sharks. 27. Fossil salmon, or smelt. 28. Macropoma, and other fishes of the chalk. 29. Reptiles of the chalk. 30. Review of the chalk formation. 31. Geology of the south-east of England. 32. Geological phenomena between London and Brighton. 33. The wealden. 34. Wealden of the Sussex coast. 35. Pounceford. 36. Sub-division, and extent of the wealden. 37. Quarries of Tilgate forest. 38. Rippled sandstone. 39. Wealden of the Isle of Wight. 40. Isle of Purbeck. 41. Petrified forest of the Isle of Portland. 42. Modern submerged forest. 43. Fossils of the wealden. 44. Fossil vegetables—ferns. 45. Clathraria and endogenites 46. Seed-vessels. 47. Fossil shells. 48. Sussex marble. 49. Fossil cypris. 50. Fishes. 51. Reptiles of Tilgate forest. 52. Fossil turtles. 53. Fossil crocodiles. 54. The Swanage crocodile. 55. The plesiosaurus. 56. The megalosaurus. 57. The iguanodon. 58. The Maidstone iguanodon. 59. Size of the iguanodon. 60. The hylæosaurus. 61. Flying reptiles. 62. Fossil birds. 63. The country of the iguanodon. 64. Sequence of geological changes. 65. Retrospect of geological mutations.

1. Introductory remarks.—The knowledge we have acquired from our investigation of the phenomena described in the previous lectures, will materially facilitate our geological progress, by enabling

us to comprehend the former effects of those agencies, by which the surface of the earth has been renovated and maintained.

The elevation of the beds of seas and rivers, and their conversion into fertile countries—the submergence of islands and continents beneath the waters of the ocean—the rapid formation of conglomerates from shells and corals on the sea shore—the accumulation of beach and gravel, and the inhumation of animals and vegetables—the slow deposition of sediment by lakes and rivers—the imbedding of innumerable generations of insects, and the formation of limestone from their almost invisible skeletons—the construction of solid stone out of fragments of bones, and rocks, shivered by earthquakes — the engulfing, in estuaries and inland seas, of land animals, birds, and reptiles—the consolidation of both organic and inorganic substances into rock, by the infiltration of flint and lime by thermal waters — the transmutation of submerged forests into coal and lignite—the destructive and conservative effects of volcanic eruptions—the conversion of sand, gravel, and clay, into homogeneous masses by heat, and even the production of metalliferous veins of gold and silver—all these phenomena have passed in review before us, although our inquiries have extended through periods which, however vast and remote in relation to the records of our race, are but brief and modern in the physical history of the earth.

The geological events previously described, although forming a connected series, may be divided into periods, each of which is marked by certain zoological characters; namely, 1st. The *modern*, or *human epoch;* 2d. the *elephantine*, characterised by the preponderance of large pachydermata; 3d. the *palæotherian*, in which animals allied to the tapir prevailed, and Europe presented a system of gulfs and lakes.

2. SECONDARY FORMATIONS.—I hasten to the consideration of another and antecedent geological epoch,—that which comprehends the Secondary Formations. Hitherto our attention has been principally directed to deposits confined within comparatively limited areas, as the basins of lakes, gulfs, estuaries, and inland seas; and accumulations of drifted materials produced by the action of torrents, rivers, and inundations. We have now arrived on the shores of that ocean, of whose spoils the existing islands and continents are principally composed; the fathomless depths of the ancient seas are spread before us, and the myriads of beings which sported in their waters, and lived and died in those profound abysses, remain, like the mummies of ancient Egypt, the silent yet eloquent teachers of their own eventful history.

A reference to the Tabular Arrangement of the Strata (Plate VII. and page 194) will show that the secondary formations constitute nine principal subdivisions, forming four natural groups, viz.

the *cretaceous*, *oolitic*, *saliferous*, and *carboniferous* systems, each containing littoral, marine, and oceanic deposits; sandstones having been formed amidst the agitated waters of the sea shores, clays in tranquil bays and gulfs, and limestones in deep water. I purpose, in the present discourse, to explain the geological characters of the first two of the series, namely, the CHALK and the WEALDEN.* The former is composed of rocks that have been accumulated in the depths of a sea of great extent; the latter, of the sediments of a vast delta; the one affording a striking illustration of the nature of *oceanic*, and the other of *fluviatile* deposits.

In the diagram (Plate VII.) the wealden (3*) is represented as an intercalation between the chalk and the oolite (3, 4), because it is of limited extent, and where absent, as in the midland counties of England and on the continent, the chalk lies upon the oolite, as will be shown in the next lecture. As both the chalk and the wealden are fully developed in the south-east of England, the phenomena about to be described may be examined with but little inconvenience; and an extensive collection of the peculiar fossils of these formations may be seen in my museum.†

* The term Weald is derived from the German *Wald*, a wood or forest. The *Weald* of Sussex was formerly an impenetrable forest, called *Anderida* by the Romans, and *Andredswald* by the Saxons.

† Now in the British Museum. See Descriptive Catalogue of the Mantellian Museum, 8vo. fifth edition.

3. The chalk formation.—The pure white limestone, called *chalk*, is known to every one; but in the nomenclature of geology, the name is applied to a group of deposits very dissimilar in their lithological composition, but agreeing in the nature of the organic remains which they contain, and evidently referable to the same geological epoch. The series essentially consists of green and ferruginous sands, clays, marls, and grey and white limestones, abounding in marine remains. With this explanation it will be convenient to employ the term in its extended sense. The chalk formation comprises the following subdivisions:—

| | |
|---|---|
| 1. Upper chalk, with flints . . . | *Craie blanche* of the French geologists. |
| 2. Lower chalk, without flints . . | |
| 3. Chalk marl . . . . . . . . . . | *Craie tufeau.* |
| 4. Firestone, malm-rock, upper green sand, or glauconite . . . . | *Glauconie crayeuse.* |
| 5. Galt, or Folkstone marl . . . . | |
| 6. Shanklin, or lower green sand . . | *Glauconie sableuse.* |

The *chalk* is generally white, but in some countries is of a deep red, and in others of a yellow colour; nodules and veins of flint occur in the upper, but seldom in the lower chalk. The *marl* is an argillaceous limestone, which generally prevails beneath the white chalk; it sometimes contains a large intermixture of green sand, and then is called *firestone*, or *glauconite*. The *galt* is a stiff, blue or black clay, abounding in shells, which frequently possess a pearly lustre. The *Shanklin*, or *lower green sand*, is a triple alternation of sands and sandstone with clays; beds of chert and fuller's earth are also found in some localities.

On the continent, the series of deposits here enumerated is largely developed, and taken as a whole, the chalk formation may be described as extending over a great part of the British Islands, Northern France, Germany, Denmark, Sweden, European and Asiatic Russia, and of the United States of North America. Over this vast extent, the organic remains present certain general characters, sufficiently obvious to determine the nature of the formation. Whether imbedded in pure white limestone, coarse sandstone, blue clay, loose sand, or compact rock, the fossils consist of the same species of shells, corals, sponges, echinites, belemnites, ammonites, and other marine exuviæ; fishes, reptiles, wood, and plants. The strata are boldly displayed along the Hampshire, Sussex, and Kentish coasts; the precipitous headland of Beachy Head, and the cliffs at Dover are well known; these natural sections exhibit the manner in which the beds have been disrupted, and thrown into various inclined positions (see Pl. 9, fig. 1). At Devizes, in Wiltshire, the strata lie nearly horizontal, and in the following order:—1. White chalk. 2. Glauconite. 3. Galt. 4. Shanklin Sands (see Pl. 9, fig. 2).

4. CHALK AND FLINT.*—The *white chalk* is

* See The Fossils of the South Downs, or, Illustrations the Geology of Sussex, 1 vol. 4to. with 42 plates. Geology of the South-East of England, 1 vol. 8vo. Dr. Fitton's Memoirs

composed of lime and carbonic acid, and may have been precipitated from water holding lime in solution, from which an excess of carbonic acid was expelled. But a large proportion of the purest chalk appears to be in great part, if not wholly, composed of the remains of corals and shells, and in some quarries whole layers are formed of the *ossicula* of star-fish and other radiaria, with microscopic species of polyparia and shells.* The nodules and veins of flint which occur in the chalk, show that water holding silex in solution must have been very abundant during the cretaceous period. The power possessed by thermal waters of dissolving silicious earth, depositing flint, and occasioning the silicification of vegetable substances, is strikingly exemplified in the Geysers of Iceland, as I have already explained (p. 83). The perfect fluidity of the silex before consolidation, is shown by the sharp impressions which the flints bear of shells and other marine bodies; and upon breaking the nodules, zoophytes, related to sponges and alcyonia, with other organic remains, are found enveloped; the silicious matter having so penetrated the delicate structure of the originals, that polished sections display the most minute organization of the inclosed bodies.

5. FLINT NODULES.—Flints, or silicious nodules,

on the Shanklin, or Green Sands, in which many of the fossils are beautifully delineated; Geological Transactions, vol. iv. New Series.

* Mr. Lonsdale.

occur in the chalk in horizontal rows, which present some degree of regularity, but are placed at unequal distances from each other. This arrangement has probably arisen from the chalk and flint having been held in suspension or solution in the same fluid, and precipitated into the basin of the ocean: when consolidation took place, the silicious molecules separated from the cretaceous, on the well-known principles of chemical affinity; the sponges and other zoophytes acting as nuclei or centres, around which the silicious matter coagulated. This process receives illustration from the fact, that when different substances in a state of extreme division are mixed together, they have a tendency to separate, and re-arrange themselves in masses more nearly homogeneous; thus in the materials prepared in the potteries, a separation of pounded flint from aluminous earth takes place, and silicious concretions are formed, if the mixture be not constantly agitated. The marked stratification of the chalk shows that it was deposited periodically; and it is not unusual to find veins of flint running through and filling up crevices in the strata beneath; an appearance that can only be attributed to the lower beds having been consolidated, and subsequently fissured, before the superincumbent stratum was precipitated.

6. Organic remains in flint.—The organic remains which usually occur in the chalk are also found in the flints; but certain fossils prevail far

more abundantly than others; a circumstance in all probability attributable to the constituent substance of the original having been favourable to the process of silicification. The softer zoophytes, as the alcyonia, spongiæ, &c. absolutely swarm in the flints; and infusoria are equally abundant. Fishes are occasionally found enveloped in a flint nodule; and their minute scales have been detected by Mr. Reade with the aid of the microscope, in almost every fragment of flint. Wood which has been perforated by lithodomi, and silicified, is not scarce; and confervæ and fuci are sometimes found floating, as it were, in the liquid silex. Bones of reptiles and fishes are often impacted in a mass of flint, but in no instance that I have observed has the silex permeated the osseous structure. When corals, echini, shells, &c. are imbedded, the substance of the fossils is calcareous, not silicious; they appear to be simply enveloped by a silicious paste, which had not the power of penetrating the interstices, nor of producing any chemical change.

7. Sulphuret of iron.—Iron pyrites is the only metalliferous ore that occurs abundantly in the chalk of England. The large nodular masses that are found on the Downs and in the ploughed fields, are commonly termed *thunderbolts*. This mineral sometimes forms groups of octahedral crystals of great elegance and regularity, and frequently occupies the cavities of shells and echini; terebratulæ and pectens also occasionally occur in masses

of this substance. The bones and scales of the fishes are invariably coloured with a ferruginous stain, arising from a curious chemical process; sulphuretted hydrogen was evolved during the putrefaction of the animal substance, but the sulphur entering into combination with the iron contained in the surrounding water, sulphuret of iron was formed, and hence the fossil fishes derived the rich colour which so beautifully contrasts with the white chalk in which they are imbedded.

8. MAESTRICHT BEDS.—I have described the usual lithological characters of the cretaceous strata, and if our observations were restricted to these deposits as they occur in England, the difference between the uppermost *secondary* formation and the superimposed *tertiary* would be most striking, both as regards the nature of the rocks and their organic remains. But, as I shall hereafter explain, the white chalk of England appears to have been formed in the profound depths of the sea, for we have rarely any intermixture of terrestrial or littoral productions; even pebbles are of unfrequent occurrence. At Castle Hill, near Newhaven (p. 223), and at Alum Bay, in the Isle of Wight (p. 224), the *cerithia* (Tab. 38, fig. 4), *turritellæ*, and other tertiary shells, abound in the sand and clay spread over the surface of the chalk, in which no similar shells can be detected. On the continent, however, there exist deposits which form, as it were, a link between the tertiary and the secondary. In

the valley of the Meuse there is a fine series of strata, the uppermost of which contains many genera of shells that are plentiful in the tertiary, and passing impereeptibly into limestone with eretaceous fossils and flint nodules, is finally lost in the chalk. At Gosau, in the Eastern Alps, beds occur which appear to belong to the same intermediate era; and in the United States, the researches of Dr. Morton have proved the existence of analogous deposits.

9. St. Peter's Mountain, near Maestricht. —The quarries of St. Peter's Mountain have long been celebrated for their remarkable fossils; but the true geological characters of the strata were first determined by Dr. Fitton. St. Peter's Mountain, in which the quarries are situated, is a cape or headland between the Meuse and the Jaar, and forms the extremity of a range of hills which bounds the western side of the valley of the Meuse. The mountain commences at the distance of a mile south of Maestricht, and extends in a direction towards Liege for about three leagues; it presents an almost perpendicular escarpment towards the river. A section of the hills affords the following succession of strata:—

1. Lowermost: white chalk, with layers of flint nodules.

2. Chalk very hard and gritty.

3. Calcareous freestone of a yellow fawn colour, abounding in fossils. Numerous layers of flint

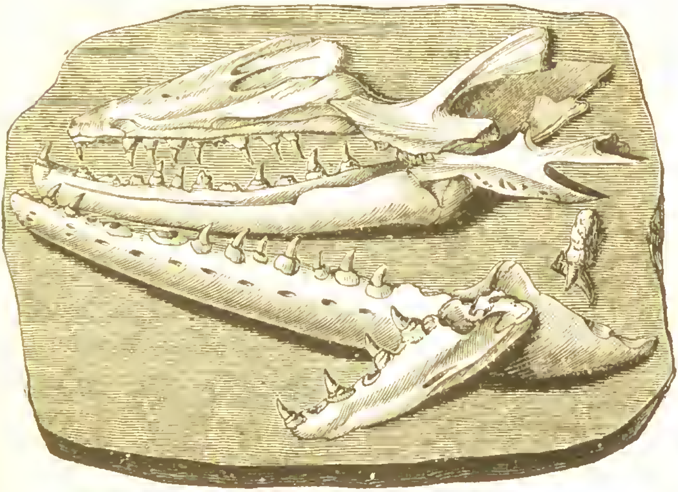
occur throughout the entire series, and present the usual characters of the siliceous nodules of the chalk formation. The Maestricht freestone is so extremely soft in the quarry, that it may easily be cut with a knife, but it becomes harder and of a lighter colour by exposure to the air.* The beds of limestone have a total thickness of about 500 feet. Excavations have for centuries been carried on in the strata of freestone, and from the immense quantities of stone removed, extensive caverns and galleries now traverse the heart of the mountain.† Shells, corals, crustacea, teeth of fishes, and other marine remains, occur in profusion; with wood perforated by lithodomi, and the bones of a large and very remarkable reptile.

10. THE MOSÆSAURUS; OR FOSSIL REPTILE OF MAESTRICHT.—The bones and teeth of an unknown animal which were occasionally found in the limestone, had long since directed the attention of naturalists to the quarries of St. Peter's Mountain. In 1770 M. Hoffmann, who was forming a collection of organic remains, had the good fortune

* The avidity of collectors has induced the quarrymen to practise an ingenious fraud upon strangers: teeth and bones of the horse, boar, &c. are carefully imbedded in blocks of the limestone while it is soft; and when the stone becomes hard, the specimens are offered for sale as genuine fossils from the quarries. The deception may be detected by immersing the specimens in water.

† See Hist. Nat. de la Montagne de St. Pierre, by Faujas St. Fond, 1 vol. 4to. with splendid engravings.

to discover a specimen, which has conferred additional interest on this locality: some workmen, on blasting the rock in one of the caverns of the



TAB. 47.—REMAINS OF THE MOSÆSAURUS.

Discovered at Maestricht, by M. Hoffmann, in 1770; now in the Museum at Paris.

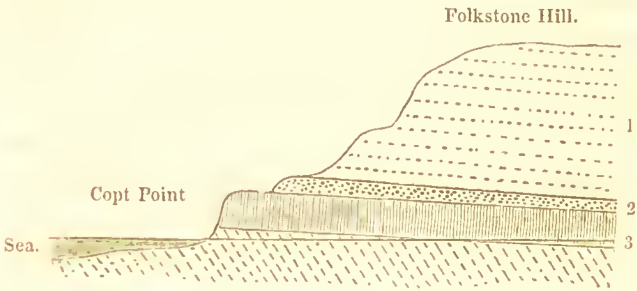
(*Four and a half feet by two and a half.*)

interior of the mountain, perceived, to their astonishment, the jaws of an enormous animal attached to the roof of the chasm. The discovery was immediately made known to M. Hoffmann, who repaired to the spot, and for weeks presided over the arduous task of separating from the rock the mass of stone containing the remains. His labours were at length repaid by the successful extrication of the specimen, which he conveyed in triumph to his house. Unfortunately, the canon of the cathedral, which stands on the mountain, claimed the fossil in right of being lord of the manor, and succeeded, by a most unjust and expensive law-suit, in obtaining this precious relic (Tab. 47). It remained in his possession for years, and Hoffmann died without regaining his treasure, or receiving any compensation. The French Revolution broke out, and the armies of the Republic advanced to the gates of Maestricht; the town was bombarded, but by desire of the committee of *savans*, who accompanied the French troops, the artillery was not allowed to play on that part of the city in which the celebrated fossil was known to be contained. In the meanwhile the canon, shrewdly suspecting why such peculiar favour was shown to his residence, concealed the specimen in a secret vault; but when the city was taken, the French authorities compelled him to give up his ill-gotten prize, which was immediately transmitted to the *Jardin des Plantes*, at Paris, where it still forms one of the most striking objects in that magnificent collection. It is but just to add, that the relatives of Hoffmann were rewarded by the French commissioners. The model of this specimen in my museum was presented to me by Baron Cuvier; it consists of the jaws, teeth, palate-bone, vertebræ, and *os quadratum*, a bone possessed by some reptiles, and in which the auditory cells are contained. There are portions of jaws with teeth of the mosæsaurus in the British Museum. The original was a reptile, holding an intermediate plaee between the *monitor* and *iguana*, about twenty-five feet long, and furnished with a tail of sueh eonstruetion as must have rendered it a powerful oar, enabling the animal to stem the waves of the oeean, of whieh Cuvier supposes it to have been an inhabitant. The vertebræ before you belong to the mosæsaurus, and were diseovered in a ehalk quarry near Lewes.* A remarkable speeimen was found a short time sinee in the ehalk of Kemp-town ; it is a vertebra of the tail, partially invested with flint, whieh has eonsolidated around it without obseuring its essential eharaeters. These teeth, from North Ameriea, eolleeted by Dr. Morton, appear to belong to the same speeies as those from Maestrieht, and additional proof is thus afforded of the original extension of the oeean of the ehalk over the area now oeeupied by the Atlantie.

11. LOWER GROUP OF THE CHALK FORMATION. —The lower division of the ehalk formation eomprises the marl, glaueonite, galt, and Shanklin sands (see page 291); and these deposits are eonstant in their eharaeter and position in the south-east of England. Near Southbourn, on the Sussex eoast, the marl, galt, and Shanklin sand, may be seen rising in sueeession on the north of the South Downs; while on the eoast of Kent, the same group emerges from beneath the ehalk on the south side of the North

* Geology of the South-East of England, p. 146.

Downs (see Plate IX. fig. 1). The relative position of these beds is well displayed at Copt Point, near Folkstone; the galt constitutes the immediate face of the cliff, and reposes on the Shanklin sand, which forms the base (Tab. 48). Eastware Bay is celebrated for the abundance of galt fossils, which are constantly being washed out of the marl by the




Tab. 48.—Section at Eastware Bay, near Folkstone.
1. The chalk. 2. Marl and glauconite. 3. Galt. 4. Shanklin sand.
(*By Dr. Fitton.*)

action of the sea. The series may be traced with more or less distinctness around the denudation of the wealden, encircling the fresh-water strata. The lowermost member, the Shanklin sand, rises into more importance towards the west, and in Surrey, Hampshire, and western Sussex, forms a line of bold hills, which run parallel with the chalk downs, and rival them in altitude; a valley of galt generally intervenes between the sand and chalk, as at Reigate (Plate IX. 1.) The Shanklin sand is subdivided into three groups. The uppermost, which is almost 100 feet in thickness, consists of red, green, white, grey, and yellow sand, with concretions of chert and chalcedony, which, in the Blackdown hills of Devonshire, contain immense numbers of silicified shells. The beds of the second group have a large admixture of clay and oxide of iron, and are so retentive, that pools of water are numerous in the tracts they occupy, and springs burst forth at their junction with the superincumbent sand. The lowermost division abounds in green and grey sands, and contains numerous concretionary masses and beds of the grey arenaceous limestone, well known as the "Kentish rag." At Shanklin Chine, in the Isle of Wight, these beds form the most characteristic feature of that picturesque spot, from whence the name of the strata is derived. In the north-east of Ireland, the Shanklin sand constitutes an important feature. On the continent it is found accompanying the upper members of the chalk formation, and is well displayed in Saxony, and along the Alps and the Carpathian mountains. In North America, arenaceous strata appear to be the equivalent of the chalk of Europe, for they abound in the usual cretaceous fossils, as ammonites, nautili, hamites, scaphites, belemnites, echinites, &c.

12. Organic remains of the chalk.—The fossils of the chalk are very numerous, and comprise all the usual forms of marine animals, with the exception of cetacea. Particular genera and species

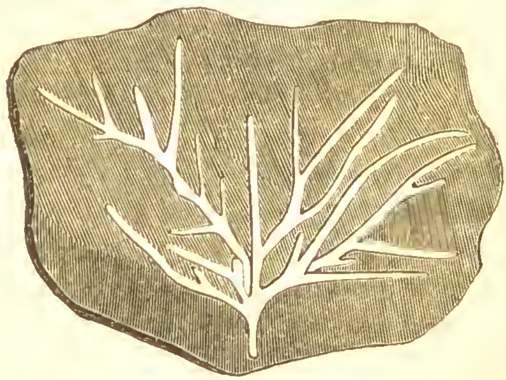
appear, however, to be restricted to certain subdivisions of the formation. Thus in the white chalk, there are many species of shells that do not occur in the other divisions of the group. The marl and galt are also characterised by peculiar forms, and the Shanklin sands abound in shells and zoophytes, that are wanting in the other cretaceous beds. The genera and species of the mollusca must therefore have varied during the period of the deposition of the chalk; some kinds prevailed at the commencement of the formation, and became extinct at a subsequent epoch; while other forms appear for the first time. Some localities are also found to abound in species which do not occur in others; these shells must therefore have been spread over limited areas; in other words, the inhabitants of the chalk ocean had geographical limits assigned them, as is the case with the existing species.

The mode of preservation varies in the different beds. The shells, stony polyparia, and radiaria of the white chalk, are generally transmuted into carbonate of lime having a spathose structure, doubtless the result of high temperature, acting under great pressure (see page 91). Their cavities are frequently filled with chalk, flint, or sulphuret of iron; in many instances they are hollow, or lined with crystals of carbonate of lime. The softer zoophytes are silicified, and there is scarcely a flint nodule in which their remains may not be traced. The bones of reptiles and fishes, and the coverings of crustacea, are in a friable state, and stained with sulphuret of iron. The teeth and seales of the fishes present a high polish, and are eoloured by a ferruginous impregnation. Wood oecurs in the state of lignite, and in brown friable masses, which quickly deeompose upon exposure to the air, but when enveloped in flint, the strueture is well preserved; like the fossil wood of the tertiary, it has evidently been drifted, and is perforated by teredines; the fissures are often filled with glittering pyrites.

In the *Galt*, the naereous eovering of the shells is commonly preserved, and the ammonites and nautili of Folkstone rival in beauty the shells of the London elay, and, like them are subject to deeomposition. The *Green-sand* fossils are generally silieified, and the whetstone pits of Devonshire are eelebrated for the variety and *chalcedonic* state of the shells in which the sandstone abounds.

The organic remains of the chalk formation already known, amount to many hundred species of shells, eorals, radiaria, &c. The most distinctive zoologieal character, is the abundanee of belemnites, eehinites, and ammonites: the latter are the shells of an extinet raee of cephalopoda, whieh appear for the first time in the ehalk, no traces of their remains having been diseovered in the tertiary formations. My collection, consisting of many thousand fossils from the chalk formations of England and America, displays the usual genera and speeies, together with many that are exceedingly rare. I will illustrate this subject by a selection of a few specimens from each class.

13. FOSSIL VEGETABLES.—The flora of the chalk, as I have already remarked, offers but little variety. Fuci, or sea-weeds, occur in some localities in great abundance. There is one species of Fucus (*Fucoides Targionii*, Tab. 49,) that abounds in the malm rock

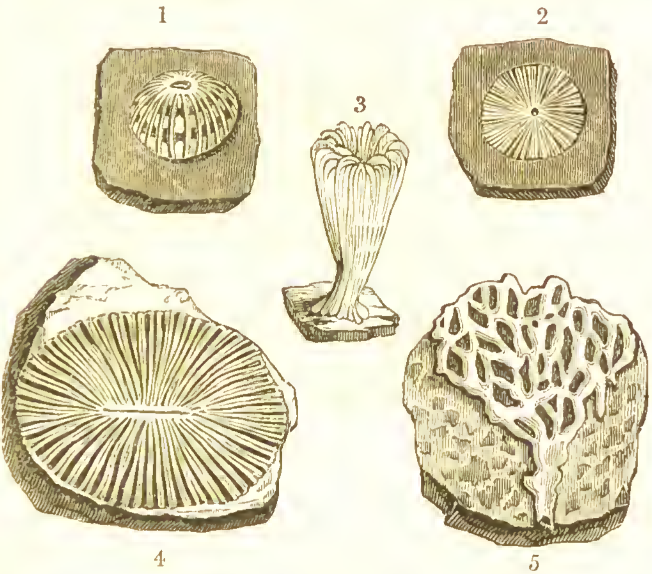


TAB. 49.—FOSSIL FUCUS IN MALM ROCK, FROM BIGNOR PARK.

(*Fucoides Targionii.*)

of Western Sussex, particularly at Bignor, the seat of my friend John Hawkins, Esq. F.R.S., where almost every fragment of the rock is marked with its meandering forms. *Confervæ* occasionally are seen in the flints. Plants allied to *Zostera* occur in the chalk of the Isle d'Aix, and drifted wood abounds in the line of junction between the galt and green sand. In the quarry of Kentish rag, of Mr. W. H. Bensted, of Maidstone, there have been discovered fir-cones, large masses of perforated wood, and the stem of a plant allied to the yucca. I reserve a more particular description of these remains for the lecture on fossil botany.

14. Fossil zoophytes.—I have already mentioned how numerous are the softer zoophytes in




Tab. 50.—Corals of the chalk.

Fig. 1. External surface of Turbinolia Königi from the galt: the fossil is attached to the marl by the disk, the base lying uppermost and exposed. 2. The disk, or upper surface of Turbinolia Königi, imbedded in galt. 3. Caryophyllia centralis from the chalk near Lewes. 4. Fungia in limestone, from Maestricht. 5. Gorgonia, from Maestricht.

the flints. In the white chalk stony corals are found but rarely, while the Maestricht beds contain them in great abundance. A small *caryophyllia*

(Tab. 50, fig. 3) is not unusual in the English white chalk, and a species of *turbinolia* (Tab. 50, fig. 1, 2) occurs in the galt. I have several unique specimens of other genera; but the absence of the large madrepores and stony corals is a remarkable fact, and accords with the evidence derived from other sources, to prove that we are examining the profound abyss of an ocean; for the economy of the living corals fits them to live only in waters of moderate depth. It would be tedious to repeat to you the names which naturalists have assigned to the zoophytes of the chalk; let it suffice to observe, that the more delicate forms, as flustra, millepora, cellepora, spongia, alcyonium, &c. are very abundant, particularly in some localities of the Shanklin sand; for instance, the quarries at Faringdon, in Berkshire, which literally swarm with polyparia. The nature of these fossils will be explained in a future lecture. There is a zoophyte, well known to collectors of Sussex pebbles by the name of *petrified sea-anemone*, from its supposed resemblance to the living actinia (Pl. 6, fig. 8); but the original of this fossil was a very different creature. From an extensive suite of specimens, I have ascertained that it was of a subglobular form, with a central opening, from which numerous tubes radiated; and these are oftentimes exquisitely preserved in flint. The external surface frequently exhibits the remains of crucial spines, similar to those possessed by the recent alcyonia.

15. RADIARIA, CRINOIDEA, &c.—The *crinoidea*, or lily-shaped animals, are but sparingly distributed in the chalk—a circumstance, as you will hereafter

TAB. 51.—MARSUPITE FROM THE CHALK.

*(Restored from specimens presented me by the Rev. H. Hoper, and G. A. Coombe, Esq. of Arundel.)*

find, strikingly contrasting with the zoological characters of the older secondary formations. Stems of *encrinites* occur in the chalk and galt; and there is a small species of *apiocrinite*, which is peculiar to this formation.* The most remarkable fossil of this class is the *marsupite*, which I have thus named from its resemblance, when closed, to a purse. The marsupite (Tab. 51) was a molluscous animal, of a

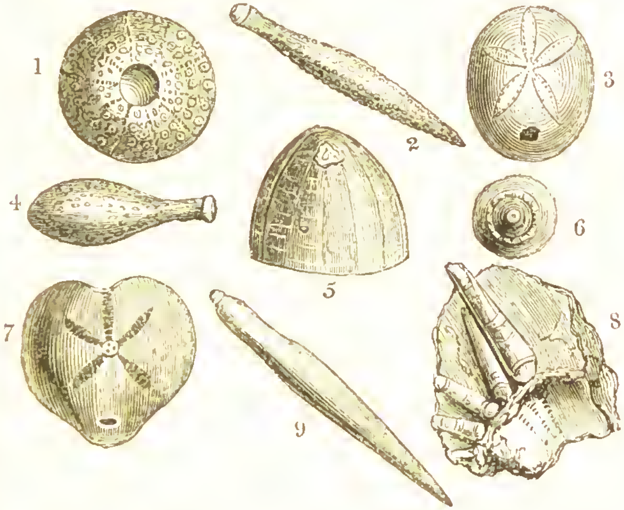
* Geology of the South-East of England, p. 111.

sub-ovate form, having the mouth, which was surrounded by arms, or tentacula, in the centre. The skeleton was composed of crustaceous, hexagonal plates, and the arms, which are subdivided into numerous branches, were formed of ossicula, or little bones; the whole was invested with a muscular tissue, or membrane. When floating, the creature could spread out the tentacula like a net, and by closing them, seize its prey and convey it to the mouth. This figure (Tab. 51) is restored from specimens which separately exhibit the parts here represented.

*Asteriæ*, or *star-fish*, are occasionally found in great perfection in the chalk; my friend, the Rev. Thomas Cooke, has discovered several remarkably fine impressions in flint, on the South Downs, near Brighton. The whetstone of Devonshire affords similar remains.

16. Echinites.—Those remarkable animals, the echini, or sea-urchins, are too well known to require minute description. Their spherical shell, or skeleton, is made up of polygonal plates, closely fitted to each other; and the surface is divided vertically, by bands like the meridians of a globe, having rows of double perforations. The shell is studded over with papillæ, which vary in size, in the different species, from mere granular points to large well-defined tubercles. To these papillæ, spines are attached, which also present great variety of figure and decoration. These are the instruments

of motion, and, as on the death of the animal, the tendons by which the spines were fixed to the shell decompose, the extreme rarity of fossil specimens, with these processes in their natural position, is readily explained. The echini, both recent and



Tab. 52.—Echinites and spines from the chalk.

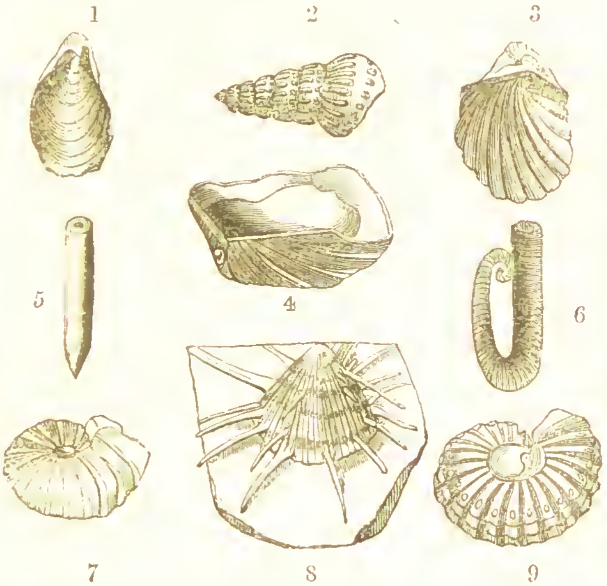
Fig. 1. Cidaris diadema. 2, 4, 9. Spines of cidares. 3. Nucleolites. 5. Ananchytes cretosus. 6. Tubercle of a cidaris. 7. Spatangus cor-marinum. 8. Spines and portion of the shell of a cidaris in flint.

fossil, differ greatly in form and structure; they are arranged into numerous sub-genera, for the convenience of study, but I can notice only a few of the usual varieties.

The helmet-shaped echinites (fig. 5) are extremely abundant, and in some localities occur in shoals, and in every gradation from the young to the adult state. Silicious casts of echini, formed by the decomposition and removal of the shell from the flint with which they were filled, are common in gravel and on ploughed lands. The cordiform variety (fig. 7) is very abundant, and gives rise to the heart-shaped flints of our gravel-pits. The elliptical species (fig. 3) is common in the green sand. The hemispherical echini are beautifully embossed with papillæ: a small species (fig. 1) is not uncommon in the chalk and flints of Kent; the larger varieties possess tubercles, surrounded by elegant margins (fig. 6), and are otherwise richly ornamented. Some spines are slender, and covered with asperities (fig. 2); others almost smooth (fig. 9), and club-shaped (fig. 4); it is seldom that the spines are found imbedded in contact with the shell (fig. 8).

17. SHELLS OF THE CHALK.—The bivalve shells, or conchifera of the chalk, are very numerous; of one genus alone (*terebratula*) above fifty species are enumerated. Oysters, scallops, areas, tellens, and other familiar marine shells abound, but the species differ from the recent. With these known genera are many which, so far as our present knowledge of the inhabitants of the deep extends, are extinct. Two or three species of *cirrus*, or *trochus*, are not unusual in the white chalk; but the simple univalves are few; and the only specimen of a large simple spiral univalve with which I am acquainted

is a species of *dolium*, figured by Sowerby.* The Mæstricht beds, as I have before remarked, offer many exceptions to the usual fossils of the chalk. A large *volute* (*V. Faujasii*) is found in the flint




TAB. 53.—SHELLS OF THE CHALK.

Fig. 1. Inoceramus concentricus. 2. Turrilites costatus. 3. Inoceramus sulcatus. 4. Inoceramus Lamarckii. 5. Belemnites Listeri. 6. Hamites. 7. Ammonites Mantellii. 8. Plagiostoma spinosum. 9. Ammonites Sussexiensis.

nodules of St. Peter's Mountain, with *baculites*, ammonites, and other characteristic chalk fossils. In the marl at Hamsey, near Lewes, I have discovered a

* Mineral Conchology, vol. v. Tab. 426.

few genera of simple univalves not previously known in the chalk. The sub-globular terebratulæ, both the common and the striated varieties, are very abundant. Another bivalve equally numerous is an elegant shell, having one valve covered with long spines (Tab. 53, fig. 8), the *Plagiostoma spinosum*,* a characteristic species of this formation. A bivalve having a fibrous structure, (*Inoceramus*, Tab. 53, fig. 4,) very brittle, with a crenulated hinge of a peculiar construction, presents numerous species; some of which are small and delicately striated, and others two feet in diameter, and deeply furrowed. The substance of these shells closely resembles in structure that of the recent *pinnæ;* from their fragility, fragments are very common in chalk, flint, and even in pyrites. The *Galt* contains two species of this genus, which appear to be restricted to this division of the chalk, and have been found in almost every locality; they are the *Inoceramus concentricus* (Tab. 53, fig. 1,) and *I. sulcatus* (Tab. 53, fig. 3); a hybrid occurs in the Folkstone beds, partaking of the characters of both. I have discovered a species of *spherulite* (*S. Mortoni*) in the chalk near Lewes, in Sussex; but *hippurites*, so common in the cretaceous strata of the continent, have not been noticed.

* *Plagiostoma.*—Viscount D'Archiac informs me that the shells of this genus are true *spondyli*, and that the triangular vacancy in the lower valve is occasioned by the loss of that portion of the hinge which characterises the recent spondylus.

The shells of the green sand amount to many hundred species: those of the whetstone pits of Blackdown, in Devonshire, are changed either into silex, jasper, or chalcedony.*

18. CEPHALOPODA, AND CHAMBERED SHELLS.—The most peculiar and striking feature of the organic remains of the chalk, as contrasted with those of the tertiary and modern deposits, is the vast preponderance of multilocular cephalopoda. In the tertiary, and in the existing tropical seas, one genus (the nautilus) occurs abundantly. The beauty, elegant form, and remarkable internal structure of the recent shell, have rendered it in all ages an object of admiration; yet an accurate knowledge of the nature and structure of the animal to which it belonged has but recently been obtained. Dr. Buckland has given a lucid account both of the recent and fossil cephalopoda;† my remarks on this subject will therefore be very concise.

The *sepia*, or *cuttle-fish* of our seas, is of an oblong form, composed of a jelly-like substance, covered with a tough skin; the mouth, which is central, is furnished with horny mandibles, much resembling the beak of a parrot. The animal has two large eyes, and eight arms, studded with rows of little cups, or suckers, which are powerful instruments both of locomotion and prehension. The

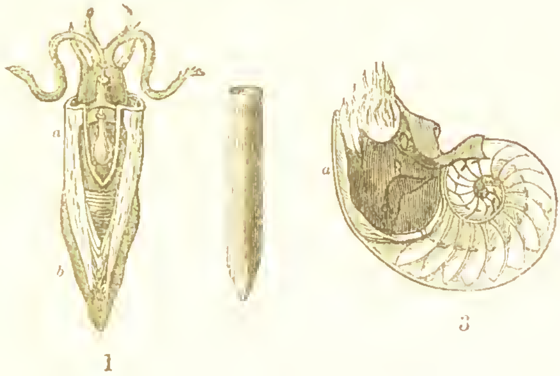
* Dr. Fitton's Memoir on the Shanklin sands contains representations of the usual shells and zoophytes of those strata.

† Bridgewater Essay, p. 333, *et seq.*

soft body of the sepia is supported by a skeleton formed of a single bone of very extraordinary structure; when dried and reduced to powder it is the substance called *pounce.* The cuttle-fish has the power of secreting a dark-coloured fluid, or ink, which it ejects when pursued, and by thus rendering the water turbid, escapes from its enemies. This fluid is contained in a bag, and forms, when properly prepared, the *sepia* colour employed in the arts, and enters into the composition of Indian ink. This brief sketch of the natural history of the cuttle-fish, will enable us to understand the habits and economy of the beings whose fossil remains I am about to describe.

19. The belemnite.—One of the most common fossils of the chalk is an elongated conical stone, of a crystalline, radiated structure, and generally of a brown colour, called *belemnite.* The pits in Sussex, Kent, Norfolk, and indeed every locality of the chalk, contain these bodies; and some limestones on the continent are almost wholly composed of them. The belemnite presents considerable variety of form, but in every species the structure consists of a spathose radiated substance, terminating in a point, (Tab. 54, fig. 2,) and having at the opposite and largest end a *conical cavity,* in which was situated a *shell* of like form, *divided into septa or chambers,* as seen in the drawing (Tab. 54, fig. 1): this shell is commonly wanting in the specimens found in the chalk. Dr. Buckland has admirably explained the

nature of the belemnite, and given the solution of a problem which had long been attempted in vain. The belemnite is the bone of a creature allied to the cuttle-fish, and in this representation (Tab. 54, fig. 1,) its situation in the body of the animal, and connexion with the ink-bag, are so clearly shown,




TAB. 54.—BELEMNITE AND NAUTILUS.

Fig. 1. Section of a restored Belemno-sepia, from Dr. Buckland; *a*, the ink-bag; *b*, the belemnite. 2. Belemnites Listeri. 3. Section of the shell, with the animal, of the recent nautilus, from Professor Owen's Memoir; *a*, the animal in the outer chamber.

as to require no further comment. The belemnite sometimes occurs with the laminated, external, horny sheath, the conical, chambered shell, the ink-bag, and the fibro-calcareous bone, in their natural position; the inspissated contents of the bag, the fossil sepia, has actually been employed as a pigment by one of our most eminent artists.

20. THE NAUTILUS.—The shell of the nautilus consists internally of a series of chambers, which

are piereed through the middle by a siphuneulus or tube, whieh extends to the remotest eell. The animal is of the nature of the sepia, and oeeupies the outer reeeptaele of the shell; it maintains a eonnexion with the inner ehambers by means of a membranous tube whieh lines the siphunele. The ehambers are internal air-cells, and the ereature has the power of filling the siphunele only, with a fluid seereted for the purpose, and of exhausting it; the differenee thus effeeted in the speeifie gravity of the animal and its shell enables the nautilus to sink or swim at pleasure. If, therefore, you imagine a euttle-fish plaeed in the outer ehamber of a nautilus, with its arms extended, and having a tube eonneeted with the siphuneulus, but neither ink-bag nor bone, these being unneeessary to an animal having the proteetion and meehanism of a ehambered shell, you will have a tolerably correet idea of the reeent nautilus. The nautilus is essentially a ground-dwelling animal, feeding on the marine plants whieh grow at the bottom of the sea. "Rumphius states that it ereeps with the shell above, and that by means of its tentaeula it ean make quiek progress along the ground."*

21. The ammonite, or cornu ammonis.—The fossils ealled ammonites, like the belemnites, also first appear in the seeondary formations; or more properly, no traees of their remains have been found in the tertiary deposits. The ammonite, so

* Dr. Buckland's Essay.

called from its supposed resemblance to the horn of Jupiter Ammon, is a fossil chambered shell, coiled up in the form of a disk, bearing a close analogy to the nautilus, but differing in the situation of the siphunculus, and in the septa by which the interior is divided. In the nautilus these partitions are entire, and their section presents a series of simple curves, (Tab. 54, fig. 3;) but in the ammonite they possess every variety of sinuosity, and the external surface of the casts of the ammonites commonly exhibits markings resembling the outlines of deeply fringed foliage; the shell is also generally decorated with flutings, ribs, or tubercles. The siphuncle, or syphon, which in the nautilus is central, is placed at the back of the ammonite. I have placed before you specimens from the Galt of Folkstone, in which the shell remains,—from Watchett, with the internal nacreous coat only,—while in this common species from Whitby the shell is altogether wanting, the specimen being a cast of the interior, formed of argillaceous iron-stone, a state in which these fossils are frequently found. In some examples, the shells and partitions of the chambers having decomposed, casts of the cells have been formed, which fit into each other, and admit of being put together, so as to show the entire shape of the ammonite. Nautili also occur in this state; and in a specimen, for which I am indebted to Miss Pearson, of Clapham, the series is complete from the commencement to the outer cell. Nearly three hundred kinds of ammonites are known in the secondary formations, certain forms being restricted to particular rocks. Thus, for example, the chalk marl of Sussex abounds in two species, (Tab. 53, figs. 7, 9,) which either are very rare, or do not occur in the white chalk above, or in the galt below; and in every locality of the marl in England, and on the continent, these species are found. But I must again refer you to Dr. Buckland's Bridgewater Essay for much important and interesting information on these subjects. I will add but one remark; the membranous tube of the siphuncle sometimes occurs in a fossil state; as may be seen in this ammonite from the chalk-marl near Lewes, which retains a large portion of the siphuncle; the black substance of these tubes has been analysed, and found to consist of animal membrane, permeated by carbonate of lime. Dr. Prout is of opinion that the black colour has originated from decomposition; the oxygen and hydrogen of the animal membrane having escaped, and carbon been evolved, as happens when vegetable matter is converted into coal, under the process of mineralization. The lime has taken the place of the oxygen and hydrogen, which existed in the pipe before decomposition.*

Ammonites vary in size from a few lines to twelve or fourteen feet in circumference; at low water on those parts of the Sussex coast where the chalk forms the base of the shore, enormous specimens

* Bridgewater Essay, p. 352.

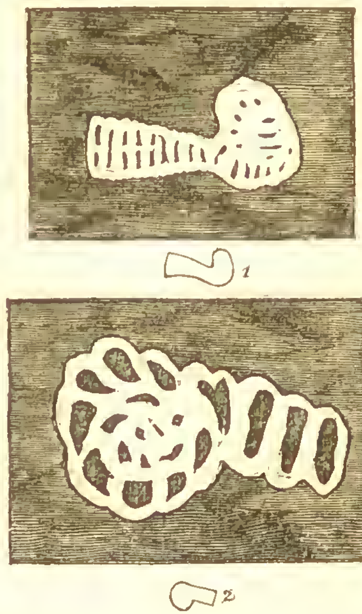
are often seen imbedded. In some limestone districts, the marble is almost wholly composed of ammonites, as in this polished slab from Somersetshire, which is adorned with most beautiful and varied sections of the inclosed shells.

22. Turrilite, hamite, &c.—Baculites, turrilites, hamites, and other genera of multilocular shells, abound in the chalk marl, galt, and Shanklin sand. The turrilite (Tab. 53, fig. 2), may be described as an ammonite twisted in a spiral, instead of a discoidal form: and the hamite (Tab. 53, fig. 6), as a similar structure in the shape of a hook, coiled up at the smaller extremity. These shells sometimes attain a large size; the turrilite before you, which is the finest example known, would if perfect exceed two feet in length; it possesses traces of the siphuncle. Hamites of gigantic proportions have been found in the Shanklin sand of Kent, by Mr. Hills, the intelligent and indefatigable curator of the Chichester Museum. The first specimens of turrilites, hamites, and scaphites, from the British strata, were discovered in my early researches, in Hamsey marl-pits, near Lewes.* The scaphite is of a boat-like form; but I must forbear entering on its description, as well as on that of many other multilocular shells, hundreds of which are microscopic, and sometimes form entire layers in the chalk.

23. Spirolinites.—There is however one genus

* Sowerby's Mineral Conchology, vol. i. Tab. 18.

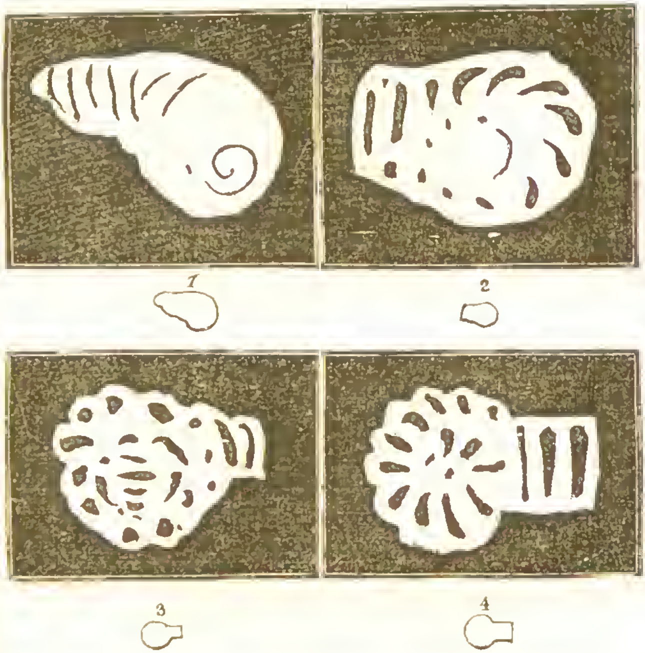
which I cannot pass over without remark; it is called, from the disposition of its chambers, the *spirolinite*, and resembles the common *nautilus spirula*, the *crozier-shell* of collectors, except that the coils, which in the recent shell are separate, are in this fossil in close apposition. Several species



Tab. 55.—Spirolinites in flint.
(*By the Marquis of Northampton, P.R.S.*)

Fig. 1. Spirolinites Lyellii. Fig. 2. S. Murchisoni.

previously unknown in the chalk, were discovered by the Marquis of Northampton, P.R.S. some years since, in the pebbles on the Brighton shores; and in flints from the chalk at Kemp-town, and other places: these minute but most interesting objects having escaped the notice of less accurate and intelligent observers. My son also has collected



TAB. 56.—SPIROLINITES IN FLINTS.

(*By the Marquis of Northampton, P.R.S. &c.*)

Fig. 1. Spirolinites Stokesii. 2. S. Mantellii. 3. S. Lyellii. 4. S. Comptoni.

several specimens from the chalk and flints near Chichester. I have great pleasure in laying before you enlarged drawings, by his lordship, of four species; the smaller figures indicate the size of the originals.*

24. Infusoria in flint.—Among the almost endless diversity of forms in which those atoms of

* Note on the Sussex spirolinites, by the Marquis of Northampton :—

"I willingly comply with your desire to communicate a short note on the Sussex spirolinites, one species of which you have been pleased to distinguish by my name. I have found these fossils in flint at Brighton, Kemp-town, Rottingdean, Lewes, Hastings, Steyning, Chichester, West Stoke, and in the Isle of Wight; and one specimen in France. I have discovered about two hundred of these minute chambered shells in flint, but only two in chalk. Some of the microscopic bodies extricated from the chalk by Mr. Lonsdale, I am inclined to think are spirolinites, but others are *foraminifera.* I have seen, as I believe, minute nummulites in the Sussex flint. The spirolinites which I have collected constitute four distinct species. 1. The one to which you have been pleased to give the appellation of *S. Comptoni.* 2. *Spirolinites Lyellii,* distinguished by the horizontal chambers, one above the other, in the coiled portion. 3. *S. Stokesii,* which I name after our friend Charles Stokes, Esq.; and this name has the further advantage of pointing out the locality, West Stoke, near Chichester, from which I obtained this unique specimen, and where other spirolinites abound. The fourth you must allow me to designate *S. Mantellii.* The distinctive characters of these species are too obvious to require detailed description. The transverse chambers in *S. Lyellii* (Tab. 55, fig. 1, and Tab. 56, fig. 3,) are a striking peculiarity of structure; in the specimen from France (Tab. 55, fig. 1), there appear indications of a siphuncle in the straight prolongation. I am inclined to believe that there are other species in my collection, but the irregularity in the fractured sections of these minute chambered shells, renders it difficult to arrive at accurate conclusions on this point.

"*Castle Ashby, January* 1, 1838." "Northampton."

animal existence, the *infusoria* (so called because numerous species abound in vegetable infusions) appear, many, like the *cypris* of which we have already spoken, possess shields or coverings, some of which are ferruginous, others calcareous, and many siliceous; the yellow film seen on the surface of stagnant water is made up of these animals. The infusoria belong to many distinct families, some having a complex organization, with a nervous, muscular, and circulating system, and digestive organs highly developed. As I shall revert to this subject in another lecture, I now only wish to call your attention to the remarkable fact, that the siliceous cases, or skeletons, of this class of beings, have been discovered in a fossil state; and that some deposits, for instance the tripoli of Bilin in Bohemia, consist almost entirely of the silicified remains of infusoria, of a species so minute, that a cubic inch of stone, weighing 220 grains, contains upwards of 41 thousand millions of these skeletons.* The distinguished naturalist, Ehrenberg, to whom we are indebted for this wonderful discovery, has also detected the remains of these animalculæ in chalk-flints, semi-opal, and other siliceous substances; and the Rev. I. B. Reade, of Peckham,† has observed in the flints of Surrey, shields of *gaillonella*, a form of infusorial animal well known to microscopic

* See a translation of Ehrenberg's Observations on these discoveries, in Taylor's Scientific Memoirs, Part III.

† Appendix II.

observers. I shall hereafter plaee before you representations of several of these objects; it is suffieient for the present to have stated the faet, that *entire masses of flint are composed of the fossilized remains of beings*, as wonderful in their strueture and organization, as any of the eolossal forms of animal existenee.* Some kinds of opal appear to have been formed of the dissolved silieious skeletons of these animaleules, and the more durable forms are seen preserved in it like inseets in amber.†

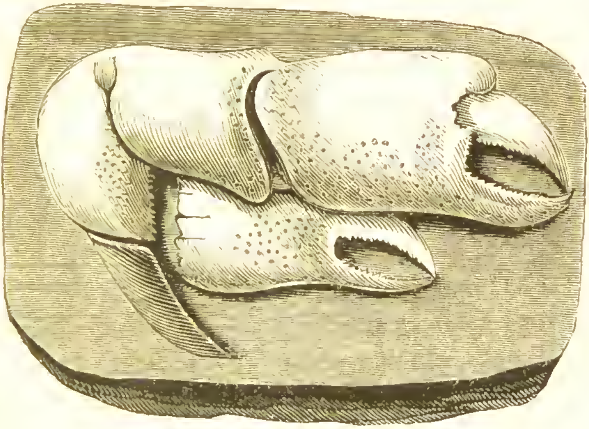
25. CRUSTACEA OF THE CHALK.—Speeies of several genera of erustaeea have been obtained from the Sussex ehalk; in some examples I have sueceeded in removing the surrounding stone, and exposing the filiform antennæ, the abdominal segments, and the tails of *astacidæ*. In the galt, the crustaeea hitherto diseovered belong to very small speeies. I have obtained from Ringmer, near Lewes, speeimens whieh, in the opinion of Dr. Leach, are extinet forms, related to Indian genera. In the Speeton elay of Yorkshire, Professor Phillips has discovered several beautiful speeies of astaeus.‡ The Shanklin sands of Kent and Dorsetshire have

* The vegetable kingdom presents us with forms equally minute. The red eolour occasionally observable in the snow at Baffin's Bay, is oeeasioned by a species of fungus (*uredo nivalis*), a full grown individual of which is but 1-1600th of an ineh in diameter; eaeh square inch of the snow is therefore covered by two millions five hundred thousand fungi.—*Bauer.*

† Lyell's Elements of Geology.

‡ *Astacus*, cray-fish.

yielded a few crustacean remains. In the limestone of St. Peter's Mountain, claws of a small kind of crab are frequently discovered (Tab. 57), but no



TAB. 57.—CLAWS OF A CRAB IN LIMESTONE, FROM MAESTRICHT.

*(Pagurus Faujasii.)*

other vestiges of the animal. Faujas St. Fond, and Latreille, have very ingeniously explained this fact, by showing that the claws belonged to a parasitical species, which like the common hermit-crab of our seas, had the body covered by a delicate membrane, the claws alone having a shelly case; hence the latter would be found in a fossil state, while of the other parts of the animal no traces would remain.

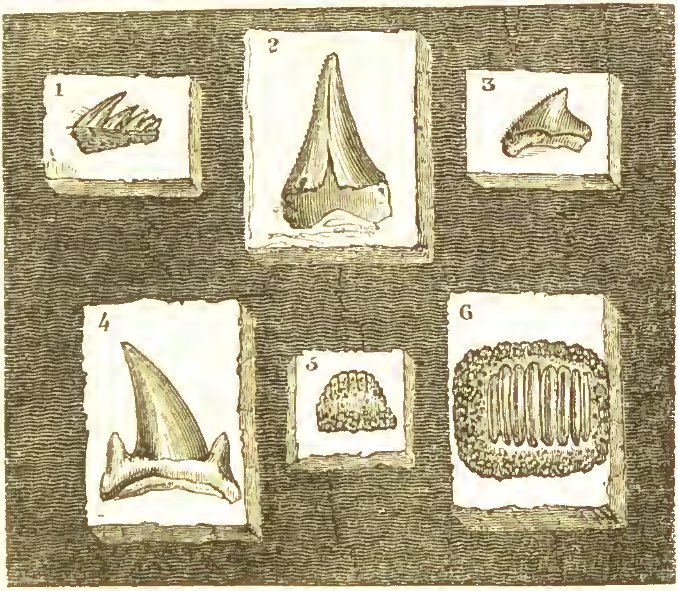
26. FISHES OF THE CHALK—SHARKS.—The fossil fishes of the chalk were known only by the teeth, which abound in almost every quarry, until my researches in the chalk-pits around Lewes

brought to light the extraordinary specimens before you, and showed how such delicate remains could be developed. The teeth for the most part belong to fishes allied to the shark; a family which in the ancient, as in the modern seas, appears to have been confined by no geographical limits. Professor Agassiz, by whose genius and perseverance this department of palæontology has been so successfully elucidated, has proposed a classification of fishes, founded upon the peculiar structure of the scales—an arrangement of great utility to the geologist, since the mutilated state in which ichthyolites so frequently occur, render futile the attempt to place them in the existing orders and genera.*

The teeth of sharks, particularly those of the genus *lamna* (Tab. 58, figs. 2, 4), are very common in the chalk, and occur occasionally in the flint; they possess a high polish, are in an excellent state of preservation, and are always single, arising from the cartilaginous nature of the jaws of the original. These examples of the recent shark show the number and variety of the teeth in an individual; by the decomposition of the jaw the teeth would be separated and drifted by the water, and therefore, in a fossil state, seldom exhibit any traces of their original position. It may, however, happen, that jaws with teeth will hereafter be discovered, for vertebræ, fin-bones, and even the shagreen skin of sharks, are preserved in some specimens in my collection. The

* See Appendix I.; and Dr. Buckland's Essay, p. 268.

broad rugous teeth (fig. 6) are sometimes found in groups of twenty or thirty; they belong to a fish allied to the shark, in which the mouth was covered




TAB. 58.—TEETH OF FISHES ALLIED TO THE SHARK, FROM THE SUSSEX CHALK.

Fig. 1. Notidanus microdon. 2. Lamna Mantellii. 3. Galeus pristodontus. 4. Lamna appendiculata. 5. Ptychodus altior. 6. Ptychodus decurrens.

with these bony processes, like a tessellated pavement. The spines, fin-bones, or rays of fishes, also occur in the chalk; and I have one splendid specimen, in which even the tendinous expansion of the muscle that moved the fin-bone is preserved.* Some of those in my eabinet belong to the same genus as the dog-fish of our eoast (*spinax acanthias*), whieh has a eurved spine in front of the dorsal fin; I place before you a reeent and fossil spine, to show their analogy. The mandible, or

TAB. 59.—MANDIBLE OF A SPECIES OF CHIMERA, FROM THE CHALK NEAR LEWES.

*(One-half the natural size.)*

jaw-bone, of a very eurious fish (the *chimera*) was one of my earliest diseoveries in Hamsey marl-pit, and I have sinee found examples in the ehalk of Lewes; other species have been diseovered in the green sand of Kent, by Mr. Bensted, and in the Kimmeridge elay, by Sir Philip Egerton.†

The remains of large fishes, belonging to that division ealled by Agassiz, *sauroid*, from their com-

* Fossils of the South Downs, Tab. xxxix.

† The naturc of these curious relics remained unknown, till Dr. Buckland asccrtained that thcy are the mandibles of several extinct species of chimera.

bining in their structure certain characters of reptiles, have been found in the chalk and green sand of Sussex and Kent. They consist of large, conical, striated teeth, bearing a resemblance to those of crocodiles, with which they were formerly confounded. I have several from the white chalk near Lewes; Mr. Bensted has discovered others in the Kentish rag, and Mr. Rose, in the galt of Cambridge.

27. Fossil salmon, or smelt.—But the most remarkable ichthyolites of the chalk, are the fishes belonging to the salmon family (*salmonidæ*), and closely related to the smelt (*osmerus*). Many years since, I succeeded in extricating from the chalk the extraordinary specimen before you.*

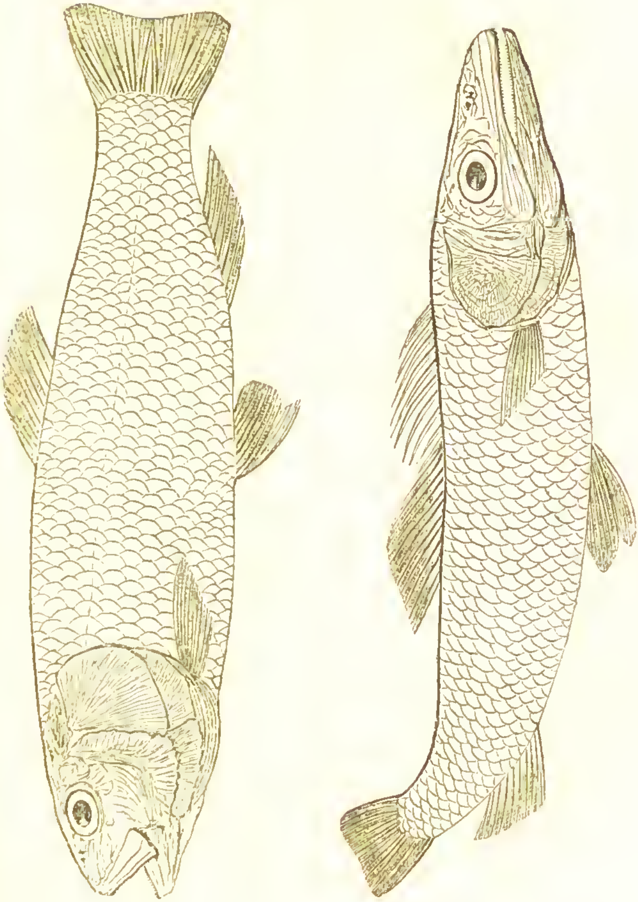
The length of the fish is nine inches, and it stands nearly six inches in relief; the back is still attached to the chalk, and the dorsal fin is exposed. There are other examples of the same species in my cabinet, which are almost equally perfect. These ichthyolites were obtained from the quarries in the immediate vicinity of Lewes, during my residence in that town. It is clear that the chalk must have surrounded the fishes while they were alive and in actual progression, and by suddenly consolidating, preserved their forms unaltered; for the body is round and uncompressed, the mouth open, and the

* A beautiful lithograph of this fossil, by Mr. Pollard, forms the frontispiece of the Catalogue of the Mantellian Museum.

fins and gills are expanded. Even to those whose curiosity has not previously been awakened to geological inquiries, the examination of these petrified inhabitants of the ocean cannot fail to excite deep interest; and I have seen the man of fashion, as well as the philosopher, gaze in mute astonishment on these "relics of a former world."

28. Macropoma, and other fishes.—I have already mentioned that the capsule of the eye remains in many specimens; this is particularly the case with those fishes (*beryx*) which have some resemblance to the dory (Tabs. 63, 64). In a sauroid fish, named *macropoma* by M. Agassiz, the membranes of the stomach are invariably preserved; this fish (Tab. 61), independently of the fact just stated, is extremely remarkable in its organization. The operculum of the gills is very large, and the scales are studded with hollow tubes. In many recent fishes, there is a row of tubular scales, forming what is called the lateral line, through which flows a fluid that lubricates the surface of the body; in the *macropoma*, every scale appears to have possessed such a mechanism.

Many of the most interesting chalk ichthyolites in my museum are figured by M. Agassiz, in his important and splendid work—"*Recherches sur les Poissons Fossiles.*" I now place before you restored figures of seven species; for comparative anatomy enables us not only to reconstruct the colossal mammalia, and the palæotheria, but also to



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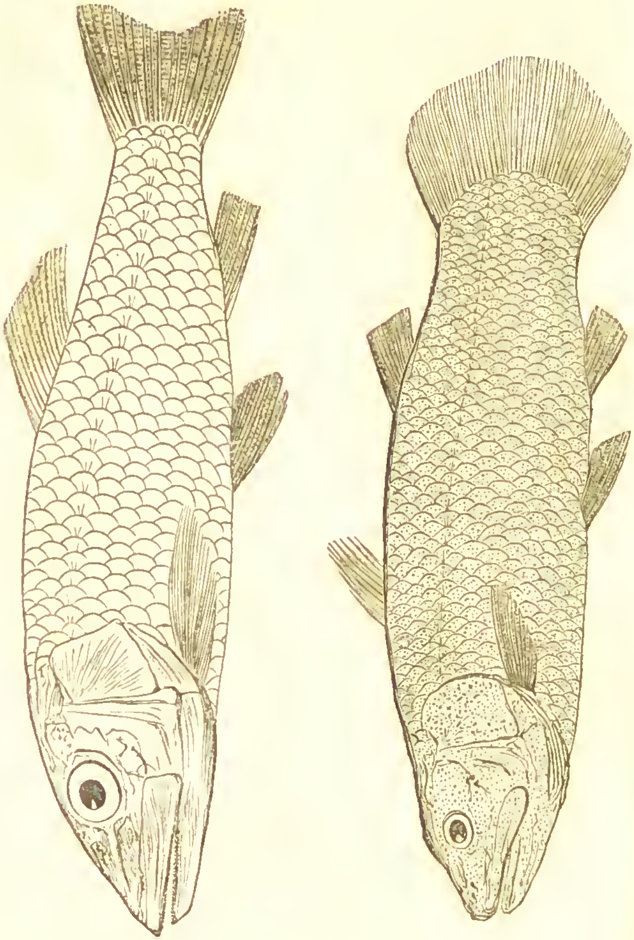
TAB. 60.—Fig. 1. OSMEROIDES MANTELLII. Length 12 inches. From Lewes Chalk-pits.

Fig. 2. ACROGNATHUS BOOPS. Natural size. *Unique.* From Lewes.



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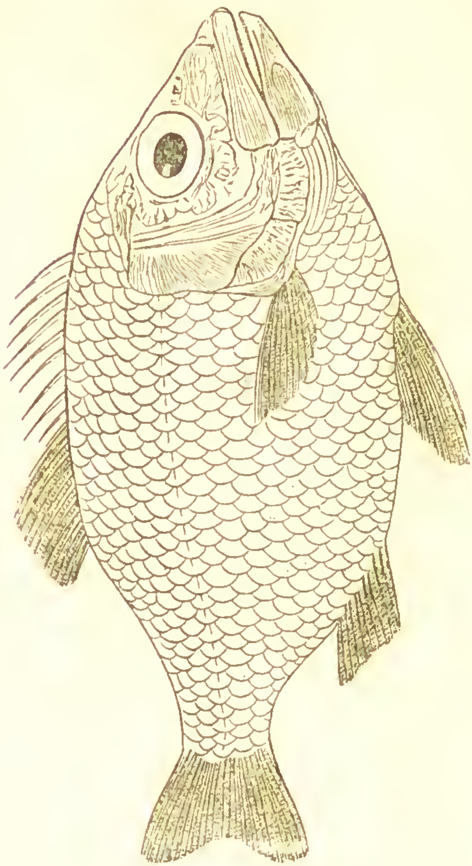
TAB. 61.—Fig. 1. AULOLEPIS TYPUS.—Length 6 inches. *Unique.* From Clayton Chalk-pit. Fig. 2. MACROPOMA MANTELLII.—Length 24 inches. From the chalk quarries near Lewes.

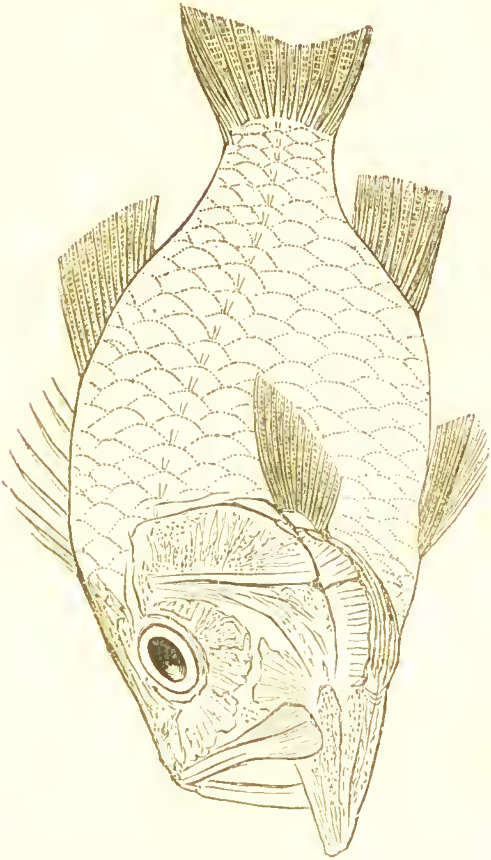
TAB. 62.—DERCETIS ELONGATUS.—Length 16 inches. From Lewes.

This species occurs abundantly in the chalk at Preston, near Brighton. The outline represents the skeleton, from a specimen in my museum; the only instance in which the skull remains.



TAB. 63.—BERYX RADIANS. Length 7 inches. From the chalk-marl, near Lewes.

This species is generally found in the chalk-marl: specimens have been collected at Clayton, Steyning, and Arundel, in Sussex.



TAB. 64.—BERYX LEWESIENSIS. Length 12 inches. From Lewes chalk-quarries.

This is the most abundant of the Sussex ichthyolites; and is called *Johnny Dory* by the workmen. Detached scales are very frequent in the chalk of the South Downs, and also in that of Kent and Surrey. Some fine specimens of this species have recently been found in the chalk of Chatham and Maidstone.

restore, with all the lineaments of life, the fishes which lived and died in the seas of the ancient world. These restorations have been drawn with great care by an eminent artist, M. Dinkel, of Munich.

The fossil fishes discovered in the South Downs amount to upwards of forty species; and there are several undescribed from the chalk of Kent, in the splendid collections of ichthyolites of Viscount Cole and Sir P. M. Egerton, Bart.

In the other sub-divisions of this formation, both in England and elsewhere, the remains of fishes occur. The slates of Glaris, in Switzerland, have long been celebrated for their ichthyolites, and by these fossils M. Agassiz was enabled to determine that those strata belong to the chalk; although the schist in which they are imbedded, as may be seen in this fine suite of specimens (collected and presented to me by the distinguished geologists above named), is a compact bituminous slate, scarcely to be distinguished from some of the most ancient of the transition series; a character which is attributable to the effects of high temperature, as will hereafter be explained.

In concluding this cursory review of the fossil fishes of the chalk, it must be remarked that all these ichthyolites are of extinct forms; and that none of the species, and even but few of the genera, occur in more recent deposits; a result in perfect accordance with that derived from the examination of the zoophytes and mollusca.*

29. Reptiles.—The remains of reptiles hitherto observed in the chalk are but few; the most important is the *Mosæsaurus Hoffmanni*, of which I spoke when describing the Maestricht deposits. The occurrence of the vertebræ of a reptile belonging to the same genus, if not species, in the Lewes chalk, and of similar teeth and bones in the equivalents of this formation in North America, are facts of great interest. Through the kindness of Mr. Charlesworth, I have inspected portions of a large jaw with teeth from the Norfolk chalk, which bear a resemblance to those of the mosæsaurus; but the symmetrical, conical form of the teeth, and other characters, show that they belong either to an unknown reptile, or to a sauroid fish. Bones of turtles are found in the white chalk of Sussex, and abundantly in the limestone of St. Peter's Mountain, and in the slate of Glaris; they belong to marine species. I have a mandible of a turtle from the Lewes chalk, which is figured by Dr. Buckland; † and a femur from Kent, discovered by Mr. Bensted. Teeth of crocodiles, from the chalk of Meudon, are mentioned by Cuvier; and very recently a specimen containing the vertebral column, ribs, and pelvis of a small lizard, in a beautiful state of preservation, was

* See Appendix K.

† Bridgewater Essay, Plate 44, fig. 3.

found in a chalk-pit near Chatham, and is in the possession of Sir P. M. Egerton.

30. REVIEW OF THE CHALK FORMATION.—The characters of the chalk formation, as shown by these investigations, are those of a vast oceanic basin, filled with the debris thrown down by its waters, and which enveloped the remains of its inhabitants; arenaceous beds prevailing in the lowermost—argillaceous in the middle—and cretaceous in the upper division of the series. Intrusions of thermal streams appear to have been abundant at certain periods; and the proofs are incontrovertible, that throughout the entire epoch of its formation, its waters swarmed with living beings of the various orders of marine existence; all, or almost all, the species being now extinct. The fuci show that it possessed a marine vegetation; and the drifted wood, fir-cones, stems, and leaves, that its shores were bounded by dry land clothed with forests; the fossil reptiles also afford additional confirmation of this inference.

31. GEOLOGY OF THE SOUTH-EAST OF ENGLAND.—From this survey of the marine formation of the chalk, we turn to the remarkable fluviatile deposits, of which the basin of the cretaceous ocean, in the south-east of England, was composed; in other countries, as I shall again have occasion to remark, that basin was formed of the oolite and other marine strata. It will now be necessary to offer a few observations on the geology of the

district in which the beds of the wealden are so largely developed.

The strata of the south-east of England constitute three principal groups. The *first* consists of the *tertiary* sands, clays, and gravel, described in the previous lecture, which occupy depressions of the chalk. The *second* is the *chalk*, (including under this term the white chalk, galt, and green sands,) which forms the most striking feature in the physical geography of the country. The upper division of the cretaceous formation constitutes the South Downs, which from the bold promontory of Beachy-head, traverse the county of Sussex from east to west, and pass by Hampshire into Surrey. From Godalming the chalk hills extend by Godstone into Kent, where the range is called the *North Downs*, and terminate in the cliffs of Dover. The lowermost member of the chalk, the Shanklin sand, appears as a chain of hills of very irregular elevation, which skirts the escarpments of the chalk downs, the galt constituting a valley between them. The *third* group is spread over the area between the North and South Downs; the most elevated masses forming a range called the *Forest-ridge*, which traverses the district in a direction nearly east and west, and is composed of alternations of sandstone, sands, shales, and clays, with a deep valley on each flank, called the *weald;* hence the geological designation of the whole series. From the central ridge of the wealden, which varies in height from

400 to 800 feet, the strata diverge on each side towards the Downs, forming an *anticlinal axis*, and finally disappear beneath the lowermost beds of the chalk. (*Vide* the section, Pl. 9, fig. 1.) There are conclusive proofs that the wealden strata were originally covered by the chalk, and that their present position and appearance are attributable to changes which have taken place subsequently to the cretaceous epoch; the wealden having been lifted up and forced through the chalk, and thus effected the partial destruction of that formation.*

32. Geological phenomena between London and Brighton. — The direct roads from London to Brighton pass over the whole series of deposits comprised in the above sketch, as well as those described in the first lecture. Proceeding from the Thames, the observer successively traverses the modern silt of the river — the ancient alluvium, containing remains of elephants and other large mammalia — and if he proceed by Reigate, his road, at Clapham and Tooting, lies over beds of clay and gravel, which are part of the ancient shores of the London basin. At Sutton he ascends the chalk hills of Surrey, and travels along elevated masses of the ancient ocean-bed just described. Arriving at the precipitous southern escarpment of the North Downs, a magnificent landscape, displaying the physical structure of the weald, and its varied and picturesque scenery, suddenly bursts

* See Geology of the South-East of England, chap. xi.

upon his view. At his feet lies the deep valley of galt in which Reigate is situated, and immediately beyond the town appears the elevated ridge of Shanklin sand, which stretching towards the west, attains at Leith-hill an altitude of one thousand feet; and to the east forms a line of sand-hills, by Godstone and Sevenoaks, through Kent, to the sea-shore. The Forest-ridge occupies the middle region, extending westward towards Horsham, and eastward to Crowborough-hill, its greatest altitude, and from thence to Hastings, having on each flank the wealds of Kent and Sussex; while in the remote distance, the unbroken and undulated summits of the South Downs appear like masses of grey clouds on the verge of the horizon.

Pursuing his route, the observer passes through Reigate, along the valley of *galt*, (see Plate 9, Section I. 2,) and over the *Shanklin sands* of Cockshut-hill, (3,) and arrives at the commencement of the wealden.* The *weald clay*, (4,) containing beds of fresh-water limestone, appears at Horley common; and while in the commencement of his journey the roads were made of broken chalk-flints, and at Reigate of cherty sandstone, the material here chiefly employed is the bluish-grey calcareous rock of the weald. At Crawley, (5,) sand and sandstone appear, and the road is composed of grit and stone, containing fluviatile shells, bones and plants. Crossing

* The reader will be able to follow this route by referring to the section, Pl. 9, fig. 1.

*Tilgate Forest* and Handcross, over a succession of elevated ridges of sandstone, and through clay valleys, produced by alternations in the strata, he descends from the sandstone ridge at Bolney, near Cuckfield, and again journeys along a district of weald clay with fresh-water limestone (4, *on the left*). *Shanklin sand*, like that of Reigate, reappears at Hickstead (3, *on the left*), and is succeeded by a tract of *galt* (2, *on the left*); and finally, entering a vale of chalk-marl, he reaches a defile in the South Downs, through which the road winds its way to Brighton; the traveller having in the course of his journey passed from one chalk range to the other, and traversed the ancient delta of the wealden.

33. THE WEALDEN. — The tertiary basin of London afforded an illustration of the process by which materials are accumulated and organic remains imbedded, in an inland sea,—that of Paris, of marine and fresh-water sediments, deposited in a gulf open to the sea on the one side, and fed by rivers and thermal springs on the other,—the lacustrine formations of Auvergne, of the gradual precipitation of strata in the tranquil waters of lakes,—the chalk, of the operations which have taken place in the profound abyss of an ocean,—while the series of deposits to which the term *wealden* is applied, presents the most striking example of an ancient fluviatile formation hitherto discovered. Yet strange as it may appear, although the wealden strata are spread over the whole area between the

North and South Downs, a tract of country traversed daily by hundreds of intelligent persons from the metropolis, their peculiar characters were entirely unknown fifteen years ago;* the whole group being supposed by geologists to belong to a series of marine clays and sands below the chalk.†

Before entering upon the description of these strata, I would remind you of what has been stated in a previous lecture, of the effects of rivers, and the nature of modern fluviatile deposits (pp. 39, 40). We found the deltas of rivers to consist of clay (or indurated mud), alternating with beds of sand and sandstone (or consolidated sand), and containing leaves, branches, and trunks of trees, fresh-water shells, works of art, bones of man, and of land

* "Until the appearance of Dr. Mantell's works on the Geology of Sussex, the peculiar relations of the sandstones and clays of the interior of Kent, Sussex, and Hampshire, were entirely misunderstood. No one supposed that these immense strata were altogether of a peculiar type, and interpolated amid the rest of the marine formations, as a local fresh-water deposit, of which only very faint traces can be perceived in other parts of England."—*Professor Phillips, Ency. Met.* p. 631. Art. *Geology.*

"It was not until the appearance of Dr. Mantell's Illustrations of the Geology of Sussex, in 1822, that the full value of the evidence which this district affords was made to appear. In that work the author clearly showed that the extraordinary remains which he had discovered in the beds of Tilgate Forest must have originated in a lake, or estuary, and have been the produce of a climate much warmer than that which is now enjoyed in England."—*Dr. Fitton's Geology of Hastings*, p. 14.

† See Conybeare and Phillips' Outlines of the Geology of England and Wales, pp. 140, 155.

animals, more or less rolled,—with boulders formed of fragments of rocks, transported by torrents from the hills, or washed out of the banks by the streams. Let us now suppose that by agencies already explained, a river has disappeared, that the sea also has changed its place, and that the bed and the delta of the river have become dry land; that towns and villages have been built upon the consolidated delta, and that its surface is either clothed with woods and forests, or under cultivation. If sections of the strata were exposed, either by natural or artificial means, and the bones of men and animals, with works of art, and remains of plants and shells, were visible in the clay or sandstone, such appearances would excite in us no surprise, because we are acquainted with the processes by which such accumulations are formed. Should an inhabitant of the new country express his wonder how brittle shells, delicate leaves, and bones, had become imbedded in the solid rock, and if when we stated the manner in which those changes had been effected, he should not only refuse his assent, but insist that the shells, leaves, and bones, were merely accidental forms of the stone, should we not feel astonished at his ignorance and prejudice? yet not a century since, and such an opinion almost universally prevailed, and is even still entertained by many! * And farther, if our

* "At Hawkhurst, in the weald of Kent, these stones (Sussex marble) abound. They consist of several laminæ, between

assumed personage admitted that the remains in question were fossil animals and vegetables, but asserted that they had been entombed in the strata by a general deluge which had softened the crust of the earth, and engulfed in the sediment of its waters the remains of animated nature,—should we not reply, that as such a catastrophe must inevitably have mingled together the remains of animals and vegetables, whether of the land, the rivers, or the seas — the regular stratification of the materials composing the delta, and the exclusive occurrence of land and fresh-water productions, were fatal to such a supposition, and afforded conclusive evidence of the correctness of our explanation of the phenomena? — by such a train of reasoning the fluviatile nature of the wealden has been determined.

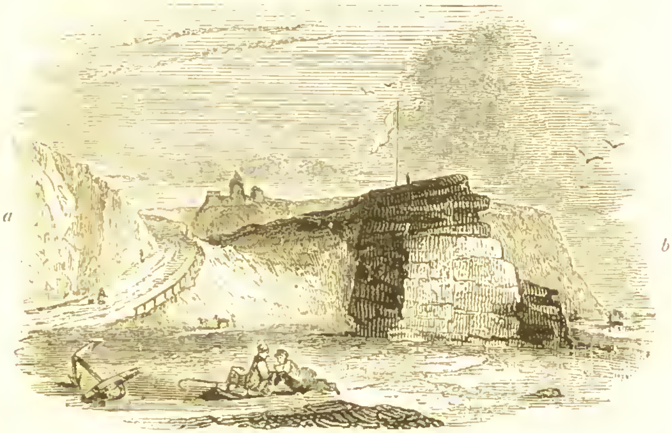
34. Wealden of the Sussex coast.—From the distribution of the wealden over the south-east of England, instructive sections have been formed by the action of the sea along the coast, between Beachy Head and Dover. From the stupendous cliffs of Beachy Head the chalk extends towards Southbourn, where beds of galt, glauconite, marl,

which grow shells, or rather half-shells, having the appearance of periwinkles of different magnitudes, according to the time of their growth. These stones naturally grow in the earth, and the shells upon them, and *are another certain proof that shells are generated in the earth, as well as in the sea, and that there is no necessary connexion between a shell and an animal.*" (! !) — *Natural History of England*, p. 193, vol. i. 1759.

and Shanklin-sand, successively emerge, forming the base of the shore, and abounding in their characteristic marine fossils. Passing over Pevensey Levels, the boundary of which, on the sea-side, is obscured by modern shingle, we arrive at Bexhill and Bulverhithe, and find the cliffs composed of finely laminated sandstone and clays; and those of St. Leonard, of similar strata, more extensively developed: sands and clays separated into very thin laminæ, alternate with conglomerates, indurated sand-rock, and a fine sandstone, of great compactness, called *grit.* At Hastings, sand and clay, with interspersions of lignite, laminated shale, grit, and sandstone, constitute a long line of high cliffs.* The general resemblance of these strata to fluviatile accumulations is most striking; the laminated structure of the clay and shales, the constant intermixture of minute portions of lignite, the absence of pebbles and shingle, and the alternations of mud and sand, are lithological characters constantly observable in river deposits. To the west of Hastings a fine mass of the strata, comprising several layers of the calciferous grit, alternating with friable sandstone, was formerly exposed on the sea shore, having at a very remote period

* See an excellent little volume on these cliffs, "*A Guide to the Geology of Hastings,*" by W. H. Fitton, Esq. M.D. F.R.S. &c. "The Geology of the South-east of England" contains a map, sections, and full details of the geological structure of this interesting district.

been separated from the adjaeent eliff. The aetion of the waves had bleaehed the projeeting layers of grit, from whieh eireumstanee the mass obtained the name of "*White rock.*" The late improvements




TAB. 65.—WHITE ROCK, HASTINGS.

(*Drawn by Miss Jane Allnutt.*)

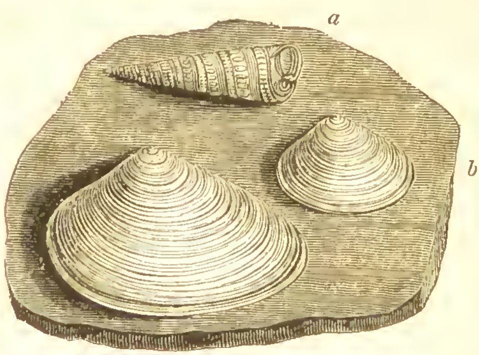
*a*, Inland cliff of laminated sandstone and clay; *b*, Cliff to the east of Hastings. The White rock is marked by the flag on its summit; it is composed of calciferous grit.

at St. Leonard's have removed all traees of this outlying portion of the Hastings beds.* The nature of the organie remains with which the strata abound will be eonsidered hereafter.

35. POUNCEFORD.—In the interior of the eountry, the quarries opened along the ridges formed by the compaet grit, afford various instruetive seetions; and the valleys, eroded by the streams, expose the shales

* Geology of the South-East of England, p. 194.

and laminated clays. Pounceford, on the estate of Lord Ashburnham, on the road to Burwash, in Sussex, presents several highly interesting sections of the argillaceous beds and limestones. Descending through a defile in the sandstones, we arrive at the bottom of a glen, along which a rapid stream, that bursts out from between the elay-partings, rushes to a distant and lower valley. On each side openings are made, to arrive at a greyish blue limestone abounding in shells, which is employed on the roads, and is also converted into lime for agricultural purposes. Where the stone lies deep, shafts are sunk from the surface, and after the extraction of the limestone, they are deserted and filled up. This




TAB. 66.—CLAY WITH SHELLS, FROM POUNCEFORD, SUSSEX.

*a*, Melanopsis attenuata; *b*, Cyclas media; *c*, Cyclas membranacea.

spot is highly interesting and picturesque; incrusting springs issue from the limestone beds, and deposit tufa on the mosses, equiseta, and land-shells:

thousands of fossil shells are strewn over the clay and shale; and stems of plants, scales of fishes, teeth of crocodiles, and other remains, are seen imbedded in the stone; while the banks, where newly exposed, exhibit numberless laminæ and alternations of shale, clay, and layers of testaceous remains.* In a visit to this place with my friend Mr. Lyell, in 1831, many new species of shells were found in the bed of the stream, having been washed out of the banks of clay; and we collected teeth of crocodiles, and bones of fresh-water turtles, and of other reptiles. Several species of *cyclas* (a fresh-water bivalve shell), and a spiral univalve, were abundant in the clay (Tab. 66); and a muscle, (named *Mytilus Lyellii*, to commemorate our excursion, Tab. 77, fig. 8,) also a fluviatile species, was found in a mass of shale that had fallen into the rivulet.

As the *grit*, or calciferous sandstone of the wealden, forms an excellent road-material, the quarries along the principal lines leading from the metropolis to the south-eastern coast, are very numerous; and those spread over the area of Tilgate and St. Leonard's Forests have been extensively worked since the increased communication between London and Brighton. This district may be described as bounded on the west by the London roads leading through Horsham, and on the east

* See Fossils of Tilgate Forest, p. 47. Geology of the South-East of England, p. 22.

by those which pass by Linfield, and Cuckfield; the Crawley road, as previously mentioned, traversing Tilgate Forest. These localities, particularly that of Tilgate, have acquired much celebrity for their organic remains, from having been the principal sources whence the specimens figured in my first work on the "Fossils of Tilgate Forest,"* were derived; but every quarry throughout the Forest-range, from Loxwood in western Sussex, to Hastings, will be found to yield the peculiar fossils of the wealden more or less abundantly.

36. SUBDIVISION AND EXTENT OF THE WEALDEN.—The wealden may be divided into several groups, each characterised by the nature of the strata, and the prevalence of certain kinds of fossils; but throughout the whole series, the fluviatile character of the formation is maintained: in the lowermost part of the series only are there any intrusions of a marine or estuary nature. Although it is not within the scope of these lectures to enter upon minute details of stratification, it will be necessary, for the elucidation of the subject, to point out the principal subdivisions of this extensive system of fresh-water deposits.†

1. WEALD CLAY (*the uppermost or latest deposit*).—Stiff blue clay, with septaria, argillaceous ironstone, and beds of shelly limestone, called *Sussex or Petworth marble*. (See the section Pl. 9, fig. I. 4.)

* See Fossils of Tilgate Forest, p. 51.

† Geology of the South-East of England, p. 182.

2. Hastings beds.—Sand and sandstones, with calciferous grit, or *Tilgate-stone,* alternating with clays and limestones.
3. Ashburnham beds.—Clays, shales, and bluish-grey limestones and sandstones.
4. Purbeck beds.—Clays, sandstones, and shelly limestone, called *Purbeck marble.* Limestone, with layers of *vegetable mould,* and trunks of trees in a vertical position—the petrified *Forest of Portland.*

Such is the assemblage of deposits which the term wealden, first employed in this acceptation by Mr. Martin,* is intended to denote. Clays, and limestone almost wholly composed of fresh-water snail-shells, occupy the uppermost place in the series; sand and sandstones, with shales and lignite, prevail in the middle; while in the lowermost, argillaceous beds, with shelly marbles or limestones, again appear; and, buried beneath the whole, is a petrified forest, in which the trees are still standing, and the vegetable mould undisturbed! The upper clay-beds and marbles form the deep valleys or wealds of Kent and Sussex—the middle series constitutes the forest-ridge. The Purbeck are obscurely seen in some of the deepest valleys of eastern Sussex; they emerge on the Dorsetshire coast, form the island or peninsula whose name they bear, and surmount the northern brow of the Isle of Portland. At the back of the Isle of Wight, the wealden beds appear beneath the Shanklin sands; and their characteristic fossils are continually washed up on the shore at Brook-point.

* Martin's Geology of Western Sussex.

Dr. Fitton* has traced the wealden beds, or rather the lowermost division, the Purbeck, in the vale of Wardour, which is a valley of denudation, in the south of Wiltshire, like that of the South-east of England, on a small scale. In this valley the various members of the chalk occur in their regular order of superposition, resting on clay and Purbeck limestone, and having the Portland stone beneath.† In France, on the coast of the Lower Boulonnais, and in the valley of Bray near Beauvais, strata of a like character are observable; the Sussex marble (*lumachelle-à-paludines*), and a fern peculiar to the wealden, have been discovered by M. Graves of Beauvais, to whom I am indebted for specimens. It is probable that the wealden may have extended over a still larger area, for the same fossil plant (*lonchopteris Mantellii*, Tab. 73) has been found in strata beneath the green-sand, in Sweden, by Professor Nillson, who informed me that several of the fossil plants from Tilgate Forest were analogous to specimens he had collected in the little island of Bornholm, off the Danish coast. Without implicitly relying upon these observations, the wealden may be considered as covering an area 200 miles in length from west to east, and 220 miles from north-west to south-east; an extent but little exceeding the delta of the Ganges or of the

* Consult Dr. Fitton's Memoir "On the Beds below the Chalk;" Geological Transactions, 1837.

† Ibid. p. 424.

Mississippi, and surpassed by that of the Quorra, which forms a surface of 25,000 square miles, being equal to the half of England. The total thickness of the wealden deposits averages about 2000 feet.*

37. QUARRIES OF TILGATE FOREST.—The quarries of Tilgate Forest, where the calciferous grit is worked, present the following series of strata :—

1. *Uppermost.* Loam or clay—from one, to five or six feet in depth. Destitute of fossils.
2. Sandstone—friable, of various shades of fawn, yellow, and ferruginous colour; in laminæ, or thin layers, occasionally containing organic remains and pebbles,—eight feet thick.
3. *Calciferous grit*, or *Tilgate stone*—a very fine sandstone, formed of sand cemented together by calcareous spar; it occurs in large masses of a concretional form, imbedded in soft sandstone. This grit has evidently been formed of loose sand, by the percolation of water charged with calcareous matter; it abounds in bones and teeth of reptiles; stems and leaves of plants; shells, &c.
4. Sandstone, with concretionary masses of grit and conglomerate formed of rolled pebbles of sandstone, jasper, quartz, indurated clay, bones and teeth of reptiles, and of fishes; rolled masses of the grit and sandstone are found in this conglomerate; the organic remains which it contains are generally much water-worn.
5. Blue clay and marl—depth unknown.

Such is the usual character of the strata exposed in the quarries around Bolney, Cuckfield, Linfield, &c. Near Horsham the fawn-coloured sandstone is more compact, and possesses a slaty structure. The thin slates are used for roofing, and the thicker beds afford good paving-stone; their surfaces are

* Dr. Fitton.

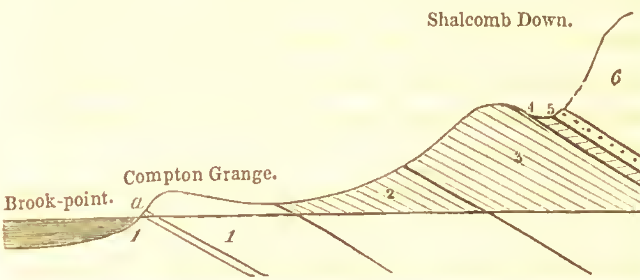
sometimes deeply furrowed by ripple-marks—an appearanee on which I will offer a few observations.

38. RIPPLE-MARKS ON SANDSTONE.—The furrowed sandstone and grit whieh are used for paving in Horsham, Crawley, and other towns and villages on the Forest-ridge and Tilgate Forest, must have attraeted the attention of most persons who have travelled from Brighton to London. The surfaee of these slabs is similar to what may be observed on the sand along the sea-shore at low water, when the ripple from the reeeding waves has been well marked; the appearanee has arisen from a similar cause (see p. 43). In many instances the stone is so rough as to be employed in stable-yards, where an uneven surfaee is required to prevent the feet of animals from slipping in passing over. It sometimes happens that when a large area of a quarry is cleared from the soil whieh eovers it, a most interesting appearanee is presented, the whole surfaee being rippled over like the strand on the sea-shore; and the speetator is struek with the eonvietion that he is standing on the sands of some aneient delta or estuary, whieh are now turned into stone. Sometimes the furrows are deep, showing that the water was mueh agitated, and the ripple strong; in other instanees the undulations are gentle, and interseeted by eross ripples, proving a ehange in the direetion of the waves. Some slabs are covered by slightly elevated, longitudinal ridges of sand, made up of gentle risings, disposed in a

crescent-like manner; these have been produced by the rills which flow back into the sea, or river, at low water. In other examples, the surface is marked by angular ridges irregularly crossing each other, like the fissures in septaria; these have obviously been caused by deposition into crevices produced in sand or mud by desiccation. A considerable portion of stone, the smooth, as well as the furrowed surfaces, is covered with small, subcylindrical markings, which are the trails formed by some species of vermes, or mollusca; but I have searched in vain for the foot-marks of the reptiles whose bones are so abundant in the sandstone. The frequent occurrence of impressions of the feet of animals in the rippled sandstone of other formations, renders it probable that sooner or later the tracks of the iguanodon and of the hylæosaurus will be discovered on the Tilgate sandstone. The deepest furrows have generally a slight coating of bluish clay, charged with minute portions of lignite, and other vegetable matter; an appearance which has been occasioned by the streams from the shore that have flowed over and coated the rippled sand. The furrowed sandstone presents an interesting example of the perfect similarity of a natural process in periods separated from each other by an immense interval of time.*

* For a particular account of the Wealden strata in the south-east of England, see "Geology of the South-East of England;" and the "Fossils of Tilgate Forest." For their nature and distribution in Wilts, &c. see Dr. Fitton's Memoir.

39. Wealden of the Isle of Wight.—Deposits partaking of the characters of those I have described, appear at the back of the Isle of Wight, and form the lowermost strata throughout the southern half of the island. Clay, identical with the weald clay, and containing Sussex marble, may be seen at Sandover bay, within a few hundred yards of the chalk, and extending into Red-cliff; and also at the junction, on the east of Fresh-water bay, where the clay abounds in the minute *shields*




Tab. 67.—Section from Brook-point to Shalcomb Down, Isle of Wight.*

1, 1, Hastings sand. *a*, Lignite and fossil trunks of trees. 2. Weald clay. 3. Shanklin sand. 4. Galt. 5. Chalk marl. 6. Chalk.

of *cyprides*. At Brook-point, the cliffs, which are about thirty feet high, are formed of clay, with inferior beds of soft sandstone; they contain lignite, and vegetable remains strongly impregnated with pyrites. Trunks of trees, of a coaly blackness, are seen imbedded in the clay of the cliff, (Tab. 67, *a*,) and scattered on the shore. In many of the stems

* Dr. Fitton. Geological Transactions, vol. iv. Pl. 10.

the ligneous structure is beautifully preserved, and veined with pyrites—other portions resemble jet. The strand at low water is seen to be formed of these fossils; and upon removing the sea-weeds which grow on the shore, the petrified trees occur imbedded in masses of clay, which have become indurated, and are now in the state of an argillaceous rock: the stems are from one to two feet in diameter, and eight or ten feet long. The knotty bark and ligneous fibre are very distinct.* Bones of the iguanodon and other gigantic reptiles are frequently found on the shore at Sandover-bay and Brook-point, being washed out of the beds of the wealden, which there form part of the basin of the British Channel.

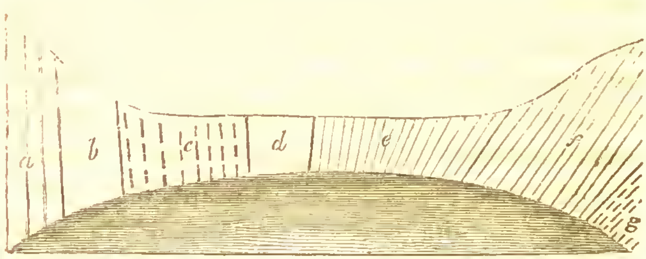
40. Isle of Purbeck.—The wealden beds are next seen in the Isle of Purbeck, which lies on the Dorsetshire coast, and is of an irregular oval form, being twelve miles in length, and seven in breadth. On the eastern promontory, vertical strata of chalk occur, and beds of clay, sandstone, and limestone lie under the displaced chalk; towards the southern extremity of the island, the Portland limestone appears.†

Purbeck has long been celebrated for its quarries, which have been worked from time immemorial, and particularly during the middle ages, the

* From Mr. Webster's interesting account of the Geology of the Isle of Wight.

† Conybeare and Phillips.

compact varieties of limestone, which bear a good polish, having, under the name of Purbeck marble, been in great request for the religious edifices of that period; and there is scarcely a cathedral, or ancient church in the kingdom, that is not ornamented with columns, pavements, or sepulchral monuments, constructed of this material. The Purbeck limestone abounds in organic remains; and the marble is a congeries of small fresh-water snail-shells (*paludina*), intermixed with the minute crustaceous coverings of a species of *cypris*. How interesting is the reflection, that the beautiful cluster-columns, the richest ornaments of Chichester cathedral, are entirely composed of the shelly coverings of snails and crustacea which lived in the river of a country inhabited by extinct colossal reptiles!




Tab. 68.—Section in one of the coves on the west of the Isle of Purbeck.

*a*, Chalk; *b*, Chalk-marl; *c*, Firestone; *d*, Galt; *e*, Shanklin sand; *f*, Purbeck beds; *g*, Portland stone.

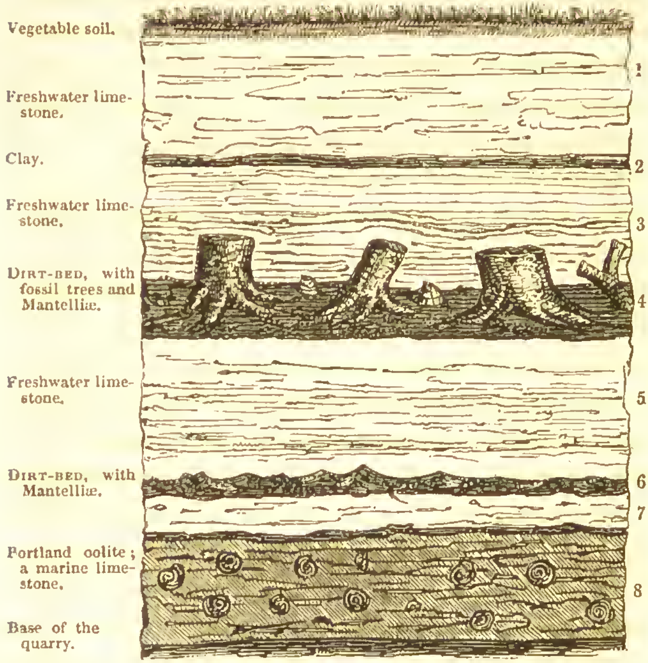
The vertical position into which so considerable a portion of the strata has been thrown, gives rise to interesting sections in the coves on the western side of the island; and, in the precipitous cliffs of those basins, the chalk, weald, Purbeck, and Portland strata, although vertical, may be seen in their regular order of succession, as is shown in this diagram (Tab. 68). No fewer than nine sections of the beds between the chalk and Portland stone (the upper division of the oolite, of which I shall speak in the next lecture) are visible within the space of five miles, in the small bays by which the coast is indented.*

41. PETRIFIED FOREST OF THE ISLE OF PORTLAND.—The island, or peninsula, of Portland is a bold headland, off Weymouth, about four miles and a half in length, and two in breadth, and is united to the main land by the Chesil beach. It presents a precipitous escarpment on the north, and declining towards the south, appears, on approaching it from the Dorchester coast, like an inclined plane, rising abruptly from the ocean. The southern extremity is flanked by low calcareous cliffs, which, from the constant action of the sea, are worn into hollows and caverns. The base of the island is formed of a blue clay (*Kimmeridge clay*), surmounted by thick beds of the oolitic limestone, known as the Portland stone, and which is extensively quarried on the northern brow of the island.

On this oolitic limestone are fresh-water strata (the lowermost beds of the wealden formation),

* Dr. Fitton, p. 215. See Conybeare and Phillips' Geology of England, p. 159.

which are characterised by phenomena of the highest interest. Mr. Webster, in his admirable geological memoir on the Isle of Wight, first directed attention to these remarkable deposits. Upon




*Total thickness about thirty feet.*

TAB. 69.—SECTION OF A QUARRY IN THE ISLE OF PORTLAND.

(*From Dr. Fitton's Memoir on the Strata below the Chalk.*)

the upper layer of marine limestone (Tab. 69, 8), which abounds in ammonites, trigoniæ, and other characteristic shells of the oolite, is a fresh-water limestone, covered by a layer of *bituminous earth,* *or vegetable mould* (4), which (as you may perceive from these specimens, collected a few years since,) is of a dark brown colour, contains a large proportion of earthy lignite, and, like the modern soil on the surface of the island, many water-worn stones. This layer is termed the *dirt-bed* by the workmen; and in and upon it are trunks and branches of coniferous trees, and plants allied to the recent *cycas* and *zamia.* Many of the trees, as well as the plants, are still erect, as if petrified while growing undisturbed in their native forests, having their roots in the soil, and their trunks extending into the upper limestone (see Tab. 69, 4). As the Portland stone lies beneath these strata, which are not much used for economical purposes, the fossil trees are removed, and thrown by as rubbish. On my visit to the island in the summer of 1832, the surface of a large area of the dirt-bed was cleared, preparatory to its removal, and a most striking phenomenon was presented to my view. The floor of the quarry was literally strewn with fossil wood; and I saw before me a petrified, tropical forest, the trees and the plants, like the inhabitants of the city in Arabian story, being converted into stone, yet still maintaining the places which they occupied when alive! Some of the trunks were surrounded by a conical mound of calcareous matter, which had evidently once been earth, and had accumulated around the bases and roots of the trees. The stems were generally three or four feet high, their summits being jagged and splintered, as if they had been torn and wrenched off by a hurricane,—an appearance which many trees in this neighbourhood, after the late storm, strikingly resembled. Some of the trunks were two feet in diameter; and the united fragments of one tree measured upwards of thirty feet in length; in other specimens, branches were attached to the stem. In the *dirt-bed*, there were many trunks lying prostrate, and fragments of branches. The fossil plants are called *Cycadeoidea* by Dr. Buckland, from their analogy to the recent cycas and zamia;* but M. Adolphe Brongniart has established a new genus for their reception, which he has named *Mantellia*. The plants occurred in the intervals between the trees; and the dirt-bed was so little consolidated, that I dug up with a spade, as from a parterre, several specimens that were standing on the very spot in which they grew, having, like the columns of Puzzuoli (Tab. 14), preserved their erect position amidst all the revolutions which had subsequently taken place, and beneath the accumulated spoils of numberless ages. The trees and plants are completely petrified by silex, or flint: you perceive that

* These plants are so common in green-houses, that their forms must be well known. In the conservatories of the Coliseum, in the Regent's Park, are fine examples of the dracæna, yucca, cycas, and several species of palms, allied to the fossil plants of Tilgate Forest. The magnificent collection of palms of the Messrs. Loddige, of Hackney, is alluded to in my work on the Fossils of Tilgate Forest.

sparks are emitted upon striking a piece of steel with this fragment of what was once a delicate plant; the common forms of the fossil *cycadeæ*,


TAB. 70.—SILICIFIED TRUNK OF MANTELLIA NIDIFORMIS.

*(Cycadites megalophyllus, Dr. Buckland *)*

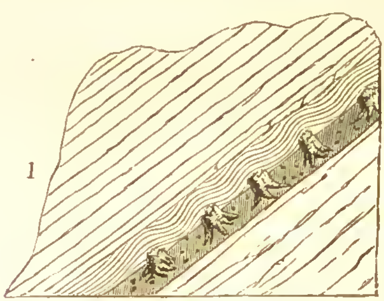
One-fourth the natural size.

*a*, Central mass of cellular tissue; *b*, Circle of radiating woody plates; *c*, Circle of cellular tissue; *d*, The case, or false bark.

(*Mantellia nidiformis* of Brongniart, Tab. 70), are called *crows' nests* by the quarry-men. Our limits will not admit of a more extended notice of these

* Dr. Buckland's Bridgewater Essay, Pl. 60.

extraordinary phenomena, and I refer you to the memoirs of Mr. Webster, Dr. Fitton, and Dr. Buckland. From what has been stated, it is evident, that after the marine strata forming the base of the Isle of Portland were deposited at the bottom of a deep sea, and had become consolidated, the bed of that ocean was elevated above the level of the waters, became dry land, and covered with forests. How long this new country existed, cannot be ascertained; but that it flourished for a considerable period is certain, from the number and magnitude of the trees of the petrified forest. In the Isle of Purbeck, traces of the dirt-bed, with the trunks of trees, are seen beneath the fresh-water limestones




Tab. 71.—Section of the cliff east of Lulworth Cove.*

1, Purbeck calcareous slate; 2, Dirt-bed, with trunks of trees; 3, Marine limestone of Portland.

of the weald; a proof, that before the deposition of the Purbeck marble could have taken place, the

* Dr. Buckland.

petrified forest must have sunk to the depth of many hundred feet. A highly interesting section occurs on the east of Lulworth Cove (Tab. 71). It presents a portion of the dirt-bed, with petrified trunks of coniferous trees, standing in the black mould in which they grew (2), interposed between the fresh-water Purbeck slate above (1), and the marine Portland limestone below (3); the whole of the strata being in an inclined position.*

42. Modern submerged forest.—An interesting modern example of the subsidence of a considerable tract of country clothed with forests, the trees remaining erect, although submerged beneath a river which still flows over them, is described by a late American writer, and will serve to illustrate the preceding remarks. The whole district, from the Rocky Mountains on the east and the Pacific Ocean on the west, and from Queen Charlotte's Island on the north to California on the south, presents one vast tract of volcanic formation. Basalt, both columnar and in amorphous masses, veins and dykes, every where occurs, and craters of extinct volcanoes are still visible. Elevations and dislocations of the strata have taken place on an immense scale; and successive beds of basalt, amygdaloidal trap, and breccia, prove the alternation of igneous action and periods of repose. Within a few miles of the cascades of the river Columbia, and extending upwards of twenty miles, trees are seen

* Bridgewater Essay, vol. ii. p. 97.

standing in their natural position, in a depth of water from twenty to thirty feet. The trees reach to high, or fresh-water mark, which is fifteen feet above the lowest level of the tide; but they do not project beyond the freshet rise, above which their tops are decayed and gone. In many places the trees are so numerous, that "we had to pick our way with the canoe, as through a forest. The water of the river was so clear, that the position of the trees could be distinctly seen down to their spreading roots, and they are standing as in their natural state before the country had become submerged. Their undisturbed position proves that the subsidence must have taken place in a tranquil manner." *

43. FOSSILS OF THE WEALDEN.—The organic remains of the wealden consist of leaves, stems and branches of plants of a tropical character; bones of enormous reptiles of extinct genera, of crocodiles, turtles, flying reptiles, and birds; of fishes of several genera and species; and fluviatile shells and crustacea. The bones are, for the most part, broken and rolled, as if they had been transported from a distance. They are strongly impregnated with iron, and are commonly of a dark-brown colour; their cavities are frequently filled with white crystallized carbonate of lime. The bones in the loose sand and sandstone are often porous and friable; those in the Tilgate grit are heavy, brittle, and well

* Journal of an Exploring Tour beyond the Rocky Mountains," by the Rev. Samuel Parker, A. M. *New York.* 1838.

preserved; in fractured portions imbedded in the limestone, the interstices are filled with calcareous spar, and the cancellated structure of the bones is often permeated by the same substance. The fossil vegetables occur bituminized, and in the state of casts of sandstone; the stems and branches are sometimes silicified; carbonized leaves and twigs are abundant in some of the strata. The shells in the clays have undergone but little change, and in many examples, the epidermis still remains; in the limestone, the substance of the shell is converted into spathose carbonate of lime. With these general remarks, I pass on to the enumeration of the principal organic remains.

44. Fossil vegetables—ferns.—From the abundance of the carbonaceous remains of vegetables in many of the laminated shales and clays of the wealden, and the occurrence of lignite, or brown-coal, in masses and layers, which sometimes alternate with beds of stone abounding in fresh-water bivalves, a striking analogy is presented to some of the divisions of the *coal measures;* and many years since, this resemblance gave rise to a search for coal at Bexhill, which, of course, proved abortive.* But notwithstanding the prevalence of vegetable matter in the strata, specimens exhibiting the nature of the original plants, in any tolerable degree of preservation, are rare; and, although my

* Geology of the South-East of England, p. xviii. Fossils of the South Downs, p. 35.

researches have been unremitting, I have obtained but few fossil plants that will admit of satisfactory conclusions as to their original structure. I shall restrict my present remarks to a brief account of the principal varieties, and the circumstances under which they occur.

Entire layers of the calciferous grit of Tilgate Forest are so full of minute portions of carbonaceous

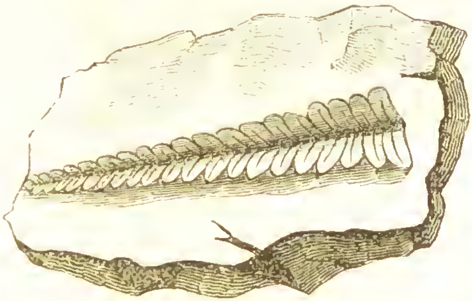
TAB. 72.—SPHENOPTERIS MANTELLII. TILGATE FOREST.

*(A fossil fern peculiar to the wealden.)*

matter,* as to acquire a dark mottled colour; and upon examining the imbedded particles, they appear

* Fossils of Tilgate Forest, Plate 3, fig. 6.

to be the detritus of plants ground to pieces by agitation in sand and water. Specimens in my possession, show that they have been principally derived from two elegant extinct species of ferns, which are peculiar to the wealden. The one is characterised by its slender and minutely divided leaflets (*Sphenopteris Mantellii*—Tab. 72); the other by the distribution of the nervures of the leaves (*Lonchopteris Mantellii*—Tab. 73). This plant has also been found in the valley of Bray by M. Graves of

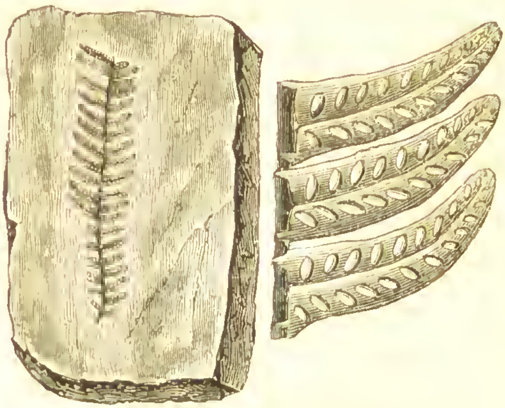


TAB 73.—PINNA OF LONCHOPTERIS MANTELLII: TILGATE FOREST.

(*A fossil fern, peculiar to the wealden.*)

Beauvais, in the lower Boulonnais in France, and in Sweden, in strata supposed to be of the same epoch as the wealden.

These ferns probably did not exceed a few feet in height; I have a stem of the *sphenopteris* which must have belonged to a plant five or six feet high. Several other species are associated with these remains; but the two plants above named constitute by far the greatest proportion of the fossil vegetables of Tilgate Forest. My cabinet



1 2

TAB. 74.—PINNA OF A FERN IN FRUCTIFICATION; IN SANDSTONE; FROM TILGATE FOREST.

Fig. 1. Natural size. 2. Three leaflets magnified.

contains a remarkable specimen, in which the parts of fructification are beautifully preserved in a silicified state (Tab. 74). Leaves of *cycadeæ,* and seed-vessels of *restiaceæ,* occur in the ironstone of Heathfield in Sussex; they are supposed to be of the same species as specimens from Bornholm. Among the plants from Heathfield are impressions which bear a close resemblance to those of the foliage of the cypress; while others appear to be referable to fuci. The stalks of a species of mare's-tail

(*Equisetum Lyellii**) abound in the blue limestone of Pounceford.

45. CLATHRARIA AND ENDOGENITES.—The stems of two plants, very distinct from each other, are the only vegetables of any considerable magnitude that occur throughout the wealden of the south-east of England. I have not detected the slightest trace of wood like that of the forest of Portland, nor observed any indications of drifted and perforated masses similar to those which are so common in the sands and clays of the chalk, and other formations.

In my former publication on the fossils of Tilgate Forest, I described the plants which I now place before you. The first species consists of stems, with numerous tubular cavities lined with quartz crystals, and presenting a structure decidedly analogous to the cacti, or euphorbiæ; they have an external coating of carbonaceous matter, and, on the removal of this coaly crust, the outer surface has a remarkably eroded appearance. The stems vary from a few inches to two feet in circumference; I have seen fragments which, when united, gave a length of five feet. There are no indications of branches, but many of the specimens taper at each end, and are of a clavated form, as in some species of cactus. Dr. Fitton describes an assemblage of these stems, which he observed before their removal, imbedded in clay, in a cliff to the east of the white-

* Geology of the South-East of England, p. 245.

rock at Hastings: they were lying with their largest diameter in a horizontal position, and consisted of a silicious stem or nucleus, coated by lignite, which not only invested the stem, but also extended beyond each extremity. The stems, when cut and polished, exhibit the monocotyledonous* structure; Count Sternberg considers them as related to the palms. This fossil vegetable, from the characters above specified, has been named *Endogenites erosa.*

Tab. 75.—Portion of the stem of Clathraria Lyellii: Tilgate Forest.

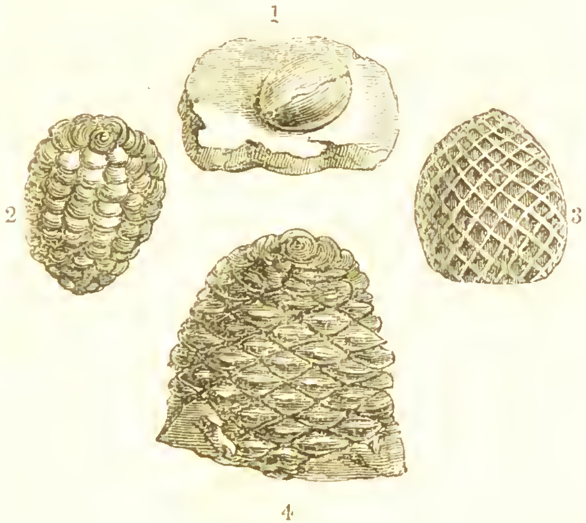
*(One-fourth the natural size.)*

The other plant (*Clathraria*† *Lyellii*) bears an analogy to the yucca, and dracæna, or dragon-blood

* Dr. Fitton has given beautiful engravings of these fossils in the Memoir already cited, Plates XIX. and XX.

† *Clathraria*, from *clathrum*, latticed or cross-barred; in allusion to the markings on the surface.

plant. Stems, with the markings of the bases of the leaves, point out the relation of this vegetable to the arborescent ferns,* while its internal structure is essentially different. This interesting specimen



Tab. 76.—Fruits and cones of the wealden.

Fig. 1. Seed-vessel of Clathraria Lyellii. 2. Cone from the Isle of Purbeck. 3. Cone from Kent. 4. Cone from Pippingford.†

(Tab. 75, p. 374) exhibits an internal axis, surrounded by a false bark, the surface of which is

* The reader may form an idea of the height and proportions of these elegant trees, by inspecting a specimen of tree-fern, forty-five feet high, from Bengal (*alsophila brunoniana*), on the staircase of the British Museum.

† Figs. 2, 3, 4, are reduced one-half from Dr. Fitton's Memoir, Pl. XXII.

scored with the markings derived from the attachment of the leaf-stalks. The clathraria has only been found in the quarries of Tilgate Forest; I have fragments of stems indicating a large size.

46. SEED-VESSELS.—Not only are the stems and leaves of plants and trees preserved in the wealden beds, but even very delicate seed-vessels are sometimes found in the grit and sandstone. A small oval carpolithe (Tab. 76, fig. 1) is the most common. M. Adolphe Brongniart considers it probable, that this may belong to the *Clathraria Lyellii.** The seed-vessels of coniferous trees also occur. These drawings (Tab. 76, figs. 2, 3, 4) are from specimens belonging to Dr. Fitton, who has figured and described them in the memoir to which I have before referred; I particularly claim your attention to fig. 4, which is half the size of the original; this beautiful cone was found imbedded in grit, in a quarry on Ashdown Forest, on the estate of Henry Shirley, Esq., and is remarkable for the double prominences on the scales.

47. FOSSIL SHELLS.—The shells of the wealden, a series of the principal species of which I have placed before you (Tab.77), belong to but few genera; and although whole tracts of country are composed of their remains, and many of the limestones are mere conglomerates of shells, yet the species are not numerous; a character perfectly agreeing with that which prevails among the existing genera of our

* See Geology of the South-East of England, p. 246.

rivers. The bivalve shells chiefly consist of muscles (referable to a genus called *unio* by conchologists), the casts of which are abundant in some of the sand-stones; and several species of cyclas,* that occur in


TAB. 77.—SHELLS AND CRUSTACEA OF THE WEALDEN.

Fig. 1. Paludina Sussexiensis, from a slab of Sussex marble. 2. Melanopsis attenuata. 3. Neritina Fittoni, natural size, and magnified. 4. Cyclas. 5. Psammobia tellinoides. 6. Unio Walteri, with other shells. 7, 9. Cypris granulosus, highly magnified. 8. Mytilus Lyellii.

myriads in the shales and clays, and resemble tertiary shells in their state of preservation. The shales of Pounceford are very like the clays of Castle Hill,

* A genus of lacustrine, or fresh-water bivalves.

Newhaven, in respect to the layers of shelly remains which occur between the strata. The grey limestones are almost wholly composed of *cyclades*, imbedded in argillaceo-calcareous cement, in which univalves are of rare occurrence.

The calciferous grit near Hastings is full of *cyclades;* but the shells are decomposed, and the casts or impressions of the interior alone remain. In the argillaceous septaria of the weald clay, casts of small univalves, also destitute of their shells, abound. In Langton-green quarry, near Tunbridge-wells, layers of argillaceous rock inclose impressions of numerous shells; and among others a remarkable species of unio (Tab. 77, fig. 6). This spiral univalve, *melanopsis attenuata* (Tab. 66, and 77, fig. 2), belongs to a freshwater genus; it occurs in the shale at Pounceford, in a beautiful state of preservation. This minute and elegant shell (Tab. 77, fig. 3), is dispersed among small snail-shells in the grit of Tilgate Forest; I have named it *neritina Fittoni*, in honour of Dr. Fitton, whose able investigations have so fully elucidated the geological character and relations of the deposits below the chalk.

48. SUSSEX, OR PETWORTH MARBLE. — The weald-clay throughout its whole extent contains beds of limestone made up of a few species of the univalve, called *paludina* (Tab. 77, fig. 1), a fresh-water snail, common in rivers and lakes. The shells are sometimes decomposed, and their casts

alone remain, the interstices being filled up with indurated marl, or calcareous concretions. In the

TAB. 78.—POLISHED SLAB OF SUSSEX MARBLE.

(*Composed of paludinæ and cyprides.*)

coarser varieties are cavities left by the decomposition of the shells; in the compact masses the shells are transmuted into calcareous spar, and the whole has been permeated by a crystalline calcareous infiltration, of various shades of grey, blue, and ochre, interspersed with pure white; polished slabs display innumerable sections of the inclosed shells, and rival in interest and beauty many foreign marbles. In these specimens you perceive the shells in relief on one side, and sections of the inclosed remains on the opposite polished surface;* very few bivalves occur in this limestone, which, from its abundance in Sussex, is commonly known by the name of *Sussex marble.* The Petworth marble, and Bethersden stone of Kent, are extensions of the same beds. In western Sussex, a beautiful marble mottled with green, blue, and grey, occasionally occurs; it is composed of large bivalves (*unio*), interspersed with a few univalves and fragments of bones of reptiles. The Purbeck marble, already described, only differs from that of Sussex in the size of the shells; the paludinæ in that limestone being of a very small species.

49. Fossil cypris.—I have stated that the wealden marbles are principally composed of fresh-water shells; but other animal remains enter into their composition, and which, although so minute as to elude common observation, possess a high degree of interest. It has been mentioned that certain crustaceous animals (*cypris*), abundant in fresh-water, having their bodies protected by shells or cases which they shed annually, occur in a fossil state in the tertiary lacustrine deposits (page 249); and I referred to the exhibition of the oxy-hydrogen microscope in illustration of the forms of the living species. The shields of various kinds of these microscopic creatures abound in the wealden clay,†

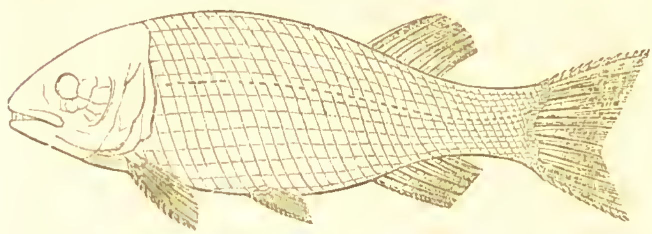
* Geology of the South-East of England, p. 184; ibid. p. 254.

† Dr. Fitton's Memoir, Pl. XXI. figs. 1, 2, 3, 4.

septaria, and limestones, and entirely fill up the cavities and interstices between the shells in some varieties of Sussex marble. In these specimens of shale from near Lewes, of septaria from Barcombe, and of marble from Laughton, by the aid of a lens, hundreds of the cases or shields of cyprides may be detected. Dr. Fitton, who has investigated the nature of these minute relics with his accustomed acumen, has discriminated several species. These enlarged drawings, from his illustrations, represent a variety in which the shells are studded with tubercles (Tab. 77, figs. 7, 9). The natural size of these objects does not, as you observe in the specimens, exceed that of a pin's head, yet in certain formations, entire layers of stone are composed of their consolidated remains, and they constitute a large proportion of the mass of many beds of Sussex marble.

50. Fishes.—Detached bones, teeth, and rays of fishes of the shark family, and of species allied to the large river-pikes of South America, are very abundant; but rarely any united portions of the skeleton, or scaly covering, are preserved; a circumstance arising from the peculiar nature of the wealden deposits. Strong, thick, enamelled, lozenge-shaped scales, possessing a high polish, and having two processes of attachment, are very abundant in the sandstones, grits, and clays throughout the wealden. In St. Leonard's and Tilgate Forests, the conglomerate contains immense numbers, asso-

ciated with small hemispherical teeth, called by the workmen *fishes'-eyes*. These scales and teeth belong to two species of *lepidotus*, or bony-pike, of which genus a recent species inhabits the rivers of South America. It is rarely that any considerable



Tab. 79.—Restored outline of the lepidotus, of the wealden.

(*By M. Agassiz.*)

number of the scales remain attached to each other in their natural position; but I have a few specimens in which large portions of the scaly covering retain their original character. These fishes must have attained a large size. In a specimen presented to me by Robert Trotter, Esq. F.G.S. of Borde Hill, near Cuckfield, a considerable mass of the united scales is beautifully preserved; it is twelve inches wide, and belongs to that part of the body where the caudal fin commences; the fish must therefore have been ten or twelve feet long, and three feet wide. Tricuspid teeth finely striated, and fin-bones of five or six species of genera belonging to the shark family, are of frequent occurrence. The fishes of the wealden are entirely distinct from those of the chalk.*

51. Reptiles of Tilgate Forest.—It will doubtless excite your surprise to learn that the whole of the enormous bones, and teeth, I have placed on the table, are those of reptiles,† and that not a vestige of any of the mammalia occurs in the wealden. Even these teeth, which so strikingly resemble the incisors of the rhinoceros, and these bones of the feet and toes, so similar in their construction and magnitude to those of the hippopotamus, all belong to oviparous quadrupeds! Many of the specimens before you can be referred to certain extinct forms of saurians, or lizards; but others are yet undetermined, in consequence of my want of leisure, and distance from any extensive collection of comparative anatomy. The determination of the fossil bones of the wealden is indeed no easy task; for while in many marine deposits, considerable portions of the skeletons, or even the entire forms, are often discovered; in the wealden, with the exception of but three or four examples,

* The following fishes of the wealden, in my museum, have been named by M. Agassiz. Pycnodus microdon, Lepidotus Fittoni, L. Mantellii, Hybodus grossiconus, H. marginalis, H. polyprion. A small species, *Lepidotus minor*, occurs in the Purbeck limestone.

† This lecture was illustrated by several hundred specimens of bones and teeth of reptiles from the wealden; many of such enormous size, that the assemblage resembled an accumulation of the disjointed skeletons of gigantic elephants or mastodons.

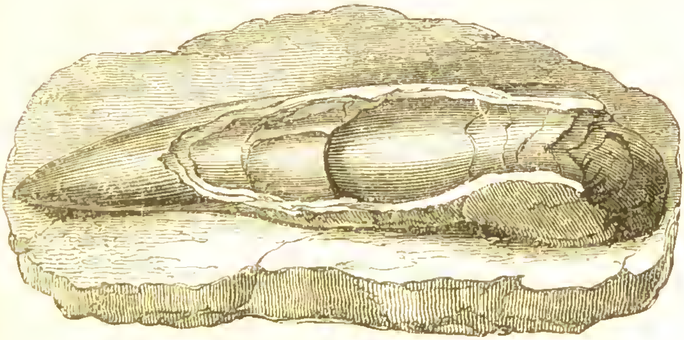
every bone, tooth, and scale, has been found apart from each other; and as if to render the task still more perplexing, the relics of several different species are scattered, as it were, at random through the rocks. Every specimen, as I have before remarked, bears evidence of having been transported from a distance; it would seem as if the limbs and carcases of the animals were floated down the stream, and rolled backwards and forwards by the tides, and the bones broken, before they became imbedded in the mud of the delta. To collect these scattered fragments, and extricate them from the solid rock; to reunite them into a whole, and assign to each skeleton of the respective animals, the bones which once belonged to it, yet not to confound the different species together—such is the labour which the comparative anatomist has to perform, who undertakes to investigate the structure of the wealden reptiles. I reserve for the next lecture some observations on the economy and habits of the reptile tribes, and will now describe the fossil relics before us.

52. FOSSIL TURTLES.—The bones and plates of turtles are very common in the Purbeck limestone, and in the grit, sandstone, and shale of Tilgate Forest. They are referable to two or more fresh-water, and one marine species; the former appear to be analogous to an *emys*, or fresh-water turtle, described by Cuvier,* as occurring in the Jura

* Oss. Foss. Tom. V. p. 232.

limestone at Soleure. It is a very flat species, and probably attained two feet in length. The ribs of a *trionyx* (which is also a fresh-water turtle), have been discovered in the shale of Pounceford, and grit of Tilgate Forest; the external surface of the ribs or dorsal plates is shagreened all over, as is usual in these turtles, which have no shelly covering, but only a thick, tough skin, or integument; the recent species inhabit the Nile and Euphrates.*

53. Fossil crocodiles.—The skeletons of the crocodiles, alligators, and gavials, those well-known reptiles of Egypt, India, and America, possess characters which render their fossil bones easily recognisable by the comparative anatomist. The



Tab. 80.—Tooth of crocodile imbedded in sandstone; from Tilgate Forest.

peculiar structure of the teeth, as you may observe in this specimen (Tab. 80), affords certain indications

* Geology of the South-East of England, p. 255.

of the original animal. The teeth of the crocodile are very numerous; they are of a conical form (Plate III. fig. 10), and consist of a succession of cones, like a series of thimbles, of various sizes, fitted into each other; they are striated externally, and have a prominent lateral ridge; as the outer tooth wears away, a new one is ready to supply its place; the teeth of the old crocodile are therefore as fresh as those of the young animal but just escaped from its shell. The interior of the teeth is never completely filled up; hence, at whatever age a tooth may be removed, there is found, either in the socket, or in the cavity of the tooth itself, a new germ, in a greater or less state of advancement, ready to occupy the place of the old one, when the latter shall be removed; and this succession is often repeated. In the fossil before us (Tab. 80), the internal structure is well displayed, in consequence of the removal of a portion of the external surface of the old tooth. Detached bones of several species of crocodiles are scattered through the Tilgate strata. From the difference observable in the form of the teeth, they appear referable to two kinds—the one belonging to that division of crocodiles, with long slender muzzles, named *gavial;* the other to a species of crocodile, properly so called,* and resembling a fossil species found at Caen. Among the hundreds of teeth and bones of crocodiles collected in the wealden, no portions of the

* Geology of the South-East of England, p. 26.

jaws, or any united parts of the skeleton, have been observed; but in the Purbeck beds a specimen has recently been discovered that affords an interesting illustration of the osteology of one of the Tilgate species.


TAB. 81.—SECTION AT SWANAGE BAY.*

1. Chalk. 2. Chalk marl. 3. Hastings beds. 4. Purbeck limestone. 5. Portland stone.

54. THE SWANAGE CROCODILE (Plate I.)—Swanage, or Swanwich, is a little town on the east of the Isle of Purbeck, the inhabitants of which carry on a brisk trade in the exportation of stone from the numerous quarries in the vicinity, there being a fine bay and good anchorage for vessels. The town stands at the mouth of the bay, about six miles E.S.E. of Corfe Castle. The section (Tab. 81), exposed by the coast, explains the geological structure of the country, and presents the following series of strata:—First, beds above the chalk; secondly, chalk; thirdly, Hastings beds; fourthly, the Purbeck limestone; and lastly, the Portland stone, which occupies the lowermost place in the series. I need not, in this place, dwell on the

* Dr. Fitton. Geological Transactions, vol. iv. Pl. X. *a*.

dislocations of these rocks, and the causes by which they have been disturbed and thrown into their present position. In the summer of 1837, the workmen employed in a quarry, in the immediate vicinity of Swanage, had occasion to split asunder a large slab of the Purbeck limestone, when, to their great astonishment, they perceived many bones and teeth on the surfaces they had just exposed. As this was no ordinary occurrence,—for although scales of fishes, shells, &c. were frequently observed in the stone, bones had never before been noticed,—both slabs were carefully preserved by the proprietor of the quarry; and fortunately my intelligent friend, Robert Trotter, Esq. happening to visit Swanage a short time afterwards, heard of the discovery, and with that liberality and ardour for the advancement of science for which he is distinguished, obtained the specimens, and presented them to me. I have cleared away the stone, so far as the brittle state of the bones will permit without injury, and they are now rendered two as interesting groups of crocodilian remains as have been discovered in this country.

In these specimens a considerable portion of the left side of the lower jaw (Pl. I. fig. 1), with two teeth attached, is preserved; many teeth are scattered over the stone, and numerous *dermal* (Pl. I. figs. 3, 3), or skin-bones, which are readily distinguished, not only by their form, but also by their deeply pitted surface. The pelvis (Pl. I. figs. 6, 7, 7, 9) is nearly entire, and there are many bones of the spine (Pl. I. figs. 2, 2), (*caudal, and dorsal vertebræ*, and *chevron-bones*, Pl. I. fig. 5), ribs (Pl. I. figs. 4, 4), and some of the long bones of the extremities.

55. THE PLESIOSAURUS.— Several bones, and vertebræ of the neck and back of the extraordinary extinct reptile, called *plesiosaurus*,* whose remains are found in such prodigious numbers in the lias, occur in the calciferous sandstone of Tilgate Forest, and prove that this animal was an inhabitant of the sea into which the river of the wealden flowed.

56. THE MEGALOSAURUS.†—The fissile limestone of Stonesfield, of which I shall speak in the next lecture, has long been celebrated for the teeth and bones of a gigantic reptile, to which Dr. Buckland has given the name of *megalosaurus*. Vertebræ, bones, and teeth of this animal have been found in the Tilgate grit, and in the clays and sandstones of the wealden, associated with the remains of turtles, crocodiles, and the still more colossal oviparous quadruped the *iguanodon*, which I now proceed to notice.

57. THE IGUANODON (Plates II. and III).—It is several years since the discovery of a mutilated fragment of a tooth led me to suspect the existence of a gigantic herbivorous animal in the strata of Tilgate Forest, which subsequent researches con-

* *Plesiosaurus*, akin to a lizard; this reptile will be described in the fifth lecture.

† *Megalosaurus*, great lizard.

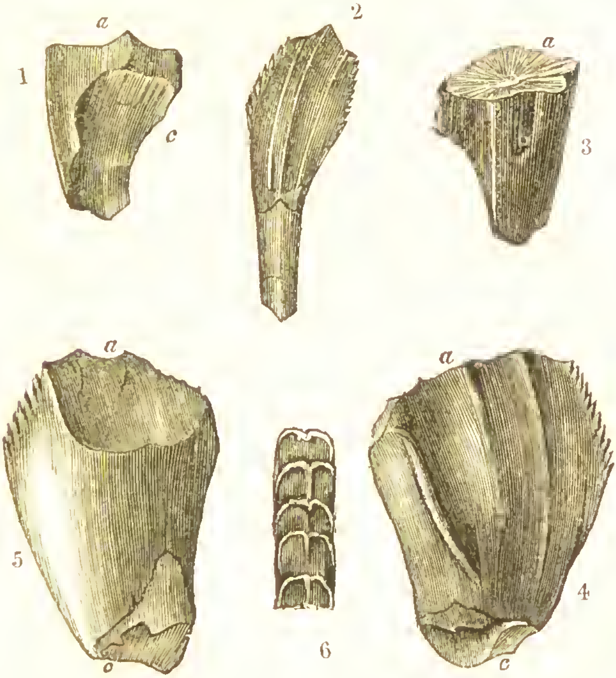
firmed.* This is the fragment: it is part of the crown of a tooth, resembling in its prismatic form the incisor of one of the herbivorous mammalia, worn by use. The enamel is thick in front and thin behind, and by this disposition a sharp cutting edge is maintained in every stage. Here, then, is a character, which if we bear in mind the principles of comparative anatomy enforced in the second lecture, (page 132,) will afford us certain indications as to the nature of the animal to which it belonged. The structure of the tooth, and its worn surface, prove that it is referable to a species that fed on vegetables; the absence of a fang, and the appearance of the base, not broken, but *indented,* show that the shank has been absorbed from the pressure of a new tooth, which has grown up and supplanted the old one; a process too familiar to require explanation.†

In the teeth before us we trace every gradation of this change, from the perfect form (Tab. 82, fig. 2, and Pl. III. fig. 3),—the partially worn specimens (Tab. 82, figs. 4, 5, and Pl. III. figs. 6, 7), to

* "On the teeth of the iguanodon, a newly-discovered fossil herbivorous reptile, from the strata of Tilgate Forest."—*Philos. Trans.* 1825.

† It cannot be requisite to notice the vulgar error that the first teeth in children have no fangs; it may however elucidate the remarks in the text, if the reader be reminded that the absence of fangs in the teeth shed in childhood, results from the absorption of the fang of the old teeth, occasioned by the pressure of those which are to supply their place.

the mere stump (figs. 1, 3), in which the crown is worn flat, and the absorption of the fang complete.




TAB. 82.—TEETH OF THE IGUANODON, FROM TILGATE FOREST.

Figs. 1, 3. Tooth worn flat, and the fang absorbed. 2. Tooth of a young animal. 4. Outer, and 5, inner, surface of a tooth of an adult. 6. Lateral view of the serrated edge of fig. 5, magnified. *a*, The surface worn by mastication. *c*, The indentation produced by pressure of the new tooth.

The teeth, when perfect, are of a prismatic form, and remarkable for the prominent ridges which extend down the front, and the serrated lateral margins of the crown (Tab. 82, fig. 6, the serrated edge magnified). By a powerful microscopic examination, the ivory in the teeth of the iguanodon is found to be composed of close-set tubes, radiating in a wavy course from the cavity of the pulp of the tooth, to the superficies, each tube being also minutely undulated; and this structure is distinctly seen on the surface in some examples.*

But although by this mode of induction the grand division of the animal kingdom to which the original belonged was ascertained, a rigid comparison of the teeth with those of recent species was necessary, to arrive at more satisfactory results. In a fossil state, no teeth at all analogous had been noticed; and after a fruitless research through the collections of comparative anatomy in London, I found, in the jaws of a recent iguana,† the type for which I had so long sought in vain. The iguanas are land lizards, natives of many parts of America and the West Indies, and are rarely met with north or south of the tropics. They are from three to five feet in length, and feed on insects and vegetables, climbing trees, and chipping off the tender shoots. They nestle in the hollows of rocks, and deposit their eggs, which are like those of turtles, in the sands or banks of rivers. The iguana is furnished with a row of very small, closely-set, pointed teeth, with serrated edges, which have no

* Professor Owen, "On the structure of Teeth," &c.

† Prepared by Mr. Stutchbury, the intelligent curator of the Bristol Institution.

distinct alveoli or sockets, but are attached at the base, and by the outer surfaces of the fangs, to the jaw, the alveolar process forming an external parapet; there is no internal bony covering. The new teeth do not, as in the crocodile, spring up in the centre of the cavities of the old, and rise through them, but proceed from near the inner part of their base, and by pressure, occasion an absorption of a portion of the fangs of the old teeth, which they ultimately displace, by destroying their adhesion to the dentary bone. The teeth of the iguana closely resemble the perfect fossil tooth, Tab. 48, fig. 2, and Plate III. fig. 3, except in size; those of the recent animal scarcely exceeding in magnitude the teeth of the common mouse. But in the iguana the teeth never present a worn surface; they are broken or chipped off by use, but not ground smooth as in the herbivora. The reason is obvious; none of the existing reptiles are furnished with cheeks or moveable coverings to their jaws, and therefore cannot perform mastication; their food or prey is seized by the teeth and tongue, and swallowed whole. But apart from this discrepancy, the teeth and mode of dentition of the fossil animal are so perfectly analogous to those of the iguana, that I have named the original the IGUANODON, signifying an animal having teeth like the iguana. In the course of the last summer I discovered in sandstone, in a quarry in Tilgate Forest, a portion of the lower jaw of the iguanodon, that confirms the inferences which many years since I ventured to deduce from the structure of the teeth alone.

From the gigantic size of the fossil teeth, as compared with the recent, I was led to conclude that many of the colossal bones, collected from time to time, in Tilgate Forest, belonged to the same kind of animal. By comparing the bones with the skeleton of the iguana, (presented to me by Baron Cuvier,) I succeeded in determining many parts of the skeleton; and at length was enabled to restore, as it were, the form of the iguanodon, and ascertain its proportions; the correctness of my deductions was shortly to be put to the test, by a discovery in a neighbouring county.

58. The Maidstone iguanodon. (Plate II.)—In May, 1834, some workmen employed in a stone-quarry, in the occupation of Mr. W. H. Bensted, of Maidstone, observed in a mass of rock which they had blasted, several portions of what they supposed to be petrified wood; they preserved the largest piece for the inspection of Mr. Bensted, who at once perceived that it was a portion of bone belonging to some gigantic animal. He therefore gave directions that every fragment should be collected, and after much labour and research, succeeded in obtaining those pieces, which are now united, and form a specimen of the highest interest; he also cleared away part of the surrounding stone, so as to expose many of

the bones, which I have since completely developed and joined together.*

The specimen consists of a considerable number of the bones, composing the inferior portion of the skeleton of an iguanodon, which, when living, must have been upwards of 60 feet in length. The bones are imbedded in the stone in a very confused manner, few of them being in their natural order of juxta-position, and all more or less flattened and distorted. The following are well displayed; and there are many fragments of others, which are too imperfect to admit of being determined.

Two *thigh-bones*, each 33 inches long.† Plate II. figs. 1, 2.
One *leg-bone* (*tibia*), 30 inches long. Plate II. fig. 3.
Metatarsal and phalangeal bones of the hind feet; these much resemble the corresponding bones of the hippopotamus. Plate II. figs. 4, 4, 4.
Two *claw-bones* (*unguical phalanges*), which were covered by the nail or claw; these correspond with the unguical bones of the land tortoise. Plate II. fig. 5; III. 2.
Two finger, or metacarpal bones of the fore-feet, each 14 inches in length. Plate II. fig. 6.
A *radius*, or bone of the fore-arm. Plate II. fig. 7.
Several *dorsal* and *caudal vertebræ* (bones of the spine and tail). Plate II. figs. 8, 8, 8.

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* Appendix L.

† The thigh-bone, or femur of the iguanodon is very remarkable (Plate III. fig. 11); it has a large trochanter (*a*) opposite to the head of the bone, and a process (*b*) on the inner side for the attachment of powerful adductor muscles; the front of the lower extremity is deeply grooved (*d*) anteriorly, as in the toad; the shaft of the bone is subquadrangular.

Fragments of several ribs. Plate II. figs. 9, 9, 9.

Two *clavicles*, or collar-bones, each 28 inches in length, resembling the bone figured Plate IV. figs. 1, 2, Geology of the South-East of England. These bones are of a very singular form, and differ essentially from any known clavicle, yet it seems impossible to assign them to any other place in the skeleton. Plate II. figs. 10, 10.

Two large flat hatchet-shaped bones, which appear to belong to the pelvis, and are probably the *ossa ilia*. Pl. II. figs. 11, 11.

A *chevron-bone*, or one of the inferior spinous processes of a vertebra of the tail. Pl. II. fig. 12.

A portion of a tooth, and the impression of another.—The preservation of these teeth is most fortunate, as the identity of the animal with the *iguanodon* of Tilgate Forest is thereby completely established.

The geological position of this specimen forms an exception to what has been previously remarked of the fossils of the wealden; for while the bones in the latter are found associated with terrestrial and fluviatile remains only, the Maidstone specimen is imbedded in a marine deposit. This discrepancy, however, in no wise affects the arguments previously advanced, as to the fluviatile origin of the strata of the wealden; it merely shows that part of the delta had subsided, and was covered by the chalk ocean, whilst the country of the iguanodon was still in existence, and the body of an iguanodon was drifted out to sea, and became imbedded in the sand; in like manner, as at the present day, bones of land quadrupeds may not only be engulfed in deltas, but also in the deposits of the adjacent ocean.

This specimen possesses a high interest, because it proves that the separate bones found in the strata of Tilgate Forest, and which I had assigned to the iguanodon, solely from analogy, have been correctly appropriated; and we obtain also a knowledge of many interesting facts relating to the structure and economy of the original. Thus as the iguana lives chiefly upon vegetables, it is furnished with long slender feet, by which it is enabled to climb trees with facility, in search of food; but no tree could have borne the weight of the colossal iguanodon,—its movements must have been confined to the land and water, and it is evident that its enormous bulk must have required limbs of great strength. Accordingly we find, that the hind feet, as in the hippopotamus, rhinoceros, and other large mammalia, were composed of strong, short, massy bones, furnished with claws, not hooked as in the iguana, but compressed as in the land tortoises; thus forming a powerful support for the enormous leg and thigh. But the bones of the hands, or fore feet, are analogous to those of the iguana,—long, slender, flexible, and armed with curved claws (Pl. III. fig. 1), the exact counterpart of the nail-bones of the recent animal; thus furnishing prehensile instruments fitted to seize the palms, arborescent ferns, and dragon-blood plants, which probably constituted the food of the original. Here we have another interesting example of that admirable adaptation of structure to the necessities and conditions of every form of existence, which is alike manifest, whether our investigations be directed to the beings around us, or to the organization of those which have long since passed away.

The stone in which the bones are imbedded is of that hard variety of the grey, arenaceous limestone, called *Kentish rag*, which is much employed in various parts of Kent, and in the west of Sussex, for building, and for repairing the roads. This *rag* belongs to the Shanklin sands, and abounds in the marine shells which are characteristic of that division of the chalk formation. In the quarry in which the remains of the iguanodon were found, Mr. Bensted has also discovered fossil wood perforated by *lithodomi*, or boring shells; impressions of leaves, stems of trees, *ammonites, nautili*, &c.; large conical striated teeth, which are referable to some species of *sauroid* fishes; scales and teeth of several other kinds of fishes, and among these, a jaw or mandible of that singular genus, the *chimera*.

59. SIZE OF THE IGUANODON.—Gigantic as must have been the animal discovered by Mr. Bensted, there are in my collection many bones which indicate proportions yet more colossal. A thigh bone (Pl. III. fig. 11), from the west of Sussex, (presented to me by J. Napper, Esq.) is 3 feet 8 inches long, and 35 inches round, at the largest extremity (*c*); and the shaft of another femur is 24 inches in circumference! The following is the result of a careful comparison of some of the fossil bones, with the corresponding ones of the iguana, with the view

of ascertaining the probable *average* size of the original animal (*vide* Geol. of the South-East of England, p. 315); we should, however, bear in mind, that some individuals must have far exceeded this estimate, and, if they bore the proportions of the recent iguana, have been upwards of 100 feet in length!

| | | |
|---|---|---|
| Length of the iguanodon from the snout to the tip of the tail | 70 | feet. |
| ,, of the head | 4½ | ,, |
| ,, of the body | 13 | ,, |
| ,, of the tail | 52½ | ,, |
| Height from the ground to the top of the head | 9 | ,, |
| Circumference of the body | 14½ | ,, |
| Length of the thigh and leg | 8 | ,, |
| Circumference of the thigh | 7½ | ,, |
| Length of the hind foot from the heel to the point of the long toe | 6½ | ,, |

Of course this calculation is offered but as an approximation; we cannot, however, for a moment doubt, that an animal possessing a body requiring thigh bones eight inches in diameter to support it, must have been of prodigious magnitude; such bones, if covered with muscles and integuments, would form limbs upwards of seven feet in circumference!

The vertebræ, or bones of the spine, are generally found detached and mutilated; but I have one specimen in which the first six (*caudal*) vertebræ of the tail are admirably preserved, and lie imbedded in a block of stone in their natural position (Pl. III.

fig. 8). The bodies of these bones are slightly concave at both extremities; the spinous processes (*a*), which are almost perfect, are 15 inches high. There are three *chevron* bones (*b*, *b*), or inferior spinous processes, lying beneath the vertebræ. The width, or rather height, of the tail to which these bones belonged, must have been at least 27 inches, and its entire length about 22 feet.

I will notice one other remarkable feature in the structure of the iguanodon. The iguanas are distinguished among the lizards by their exuberant dermal appendages; some have serrated processes or spines on the back, as in this specimen from Barbadoes, presented to me by R. I. Murchison, Esq., late President of the Geological Society; and others on the tail; while many have warts and horny protuberances on the head and snout. The extraordinary relic before you, is the FOSSIL HORN of the iguanodon (Plate III. fig. 5), from Tilgate Forest.* It is composed of bone, and bears marks on its surface of the integument with which it was invested; it is four inches high; the base, which is of an irregular elliptical form, is 3.2 inches by 2.1. In this additional analogy between the iguanodon and the iguana, we perceive another instance of that law of co-relation of form of which our researches have afforded so many examples.

The fossil plants with which the remains of the

* See Geology of the South-East of England, p. 312. Plate III. fig. 5.

iguanodon are associated, were furnished with tough, thiek stems, like those of the palms, tree-ferns, yucca, &c. These probably eonstituted the food of the original; and the peeuliar strueture of its teeth was evidently required, and admirably adapted, for the mastication of sueh vegetable produetions.

60. THE HYLÆOSAURUS (*Wealden lizard*, Pl. IV.)—In the summer of 1832, I diseovered, in the limestone of Tilgate Forest, the remains of a reptile, not less extraordinary than the iguanodon, and which I have named *hylæosaurus*, to denote its relation to the wealden formation. A bloek of caleiferous grit had been broken up by the quarrymen, and a great part of it thrown upon the road, as it was not supposed to eontain any thing interesting. Aecidentally visiting the quarry, I noticed indications of bones in several pieees of stone on the road-side, and therefore directed that the remaining portions should be colleeted, and sent to my residence. Having cemented the fragments together, and ehiselled off the hard grit in whieh the bones were wholly imbedded, and to whieh they are still attaehed, I succeeded, after mueh labour, in displaying a considerable portion of the skeleton of a reptile, whieh *blends the osteology of the crocodile with that of the lizard.* The vertebræ of the neck (Pl. IV. 1), several of the back (Pl. IV. 2), many ribs (Pl. IV. 3), and the bones of the *sternum* (Pl. IV. 6), or ehest, remain; there are also *dermal*, or skin-bones, which, in animals of this family, support the large scales.

But the most extraordinary parts, are many *enormous, angular, spinous bones* (Pl. IV. 4, 5), whieh lie in the direetion of the vertebral eolumn, and evidently extended like a serrated fringe along the baek of the animal. Many of the existing lizards, partieularly the *cyclura*, have remarkable appendages of this kind. This figure, from Dr. Harlan's valuable work, shows how largely these eurious proeesses are developed in some speeies.*

Tab. 83.—Cyclura carinata.

(*A recent lizard, allied to the iguana. Dr. Harlan.*)

The length of the hylæosaurus was probably about twenty-five feet. In the same bloek of stone were masses of vegetable remains, with seed-vessels, and stems of *Clathraria Lyellii*.† I have lately obtained many bones of this extraordinary ereature from a bed of elay near Crawley; and also a most interesting speeimen of the vertebral eolumn, eom-

* Medical and Physical Researches, by R. Harlan, M.D., F.G.S., 8vo. Philadelphia, 1835.

† Geology of the South-East of England, p. 316, Pl. V. is an excellent lithograph of this specimen, by Mr. Pollard, of West-street, Brighton.

prising nearly thirty vertebræ of the tail and back, with many *dermal and spinous bones*, ribs, &c. exhibiting very peculiar osteological characters. The teeth of the hylæosaurus are unknown; but in the quarries where the bones of that reptile were discovered, I have found teeth of a very peculiar form (Pl. III. fig. 4), which appear to have belonged to a reptile, and are entirely distinct from those of the megalosaurus, iguanodon, crocodile, and plesiosaurus, whose remains occur in the Tilgate strata.

61. Flying reptiles, or pterodactyles.—The remains of thin and slender bones, evidently belonging to animals capable of flight, were among my earliest discoveries in the strata of Tilgate Forest. Some of these bones appear to be referable to those singular extinct creatures called *pterodactyles*, or *wing-toed* reptiles, which had a beak like a bird, a long neck, and a wing sustained principally on an elongated toe. It is sufficient in this place, merely to notice the occurrence of these remains in the wealden; the subject will be resumed in the succeeding lecture.

62. Fossil birds.—In describing the fossil remains of the animals of the older tertiary epoch, it was stated that several recent genera of birds were contemporaneous with the palæotheria (page 231); but that no traces of this class of animated nature had been found in the chalk, or in strata of an earlier date. The discovery of the undoubted remains of birds in the grit of Tilgate Forest,

became, therefore, a fact of great interest and importance in the physical history of the globe. After selecting the bones which appeared to belong to pterodactyles, several remained which bore so striking a resemblance to those of *waders*, that I ventured to describe them as such in my work on the Fossils of Tilgate Forest; and this opinion was corroborated by Baron Cuvier, to whom I showed the specimens on his last visit to England. Subsequently, I have obtained the inferior portion of a leg-bone (*tarso-metatarsal*), in which the oval cicatrix, or articulation for the hind toe, is distinctly visible, and proves unquestionably that the bone belonged to some kind of wader, perhaps a heron; the position of the hind toe in birds, varying in accordance with the habits and economy of the respective orders (page 136). These are the most ancient remains of birds that have hitherto been discovered.*

63. THE COUNTRY OF THE IGUANODON.—By this survey of the strata and organic remains of the wealden, we have acquired data from which, by the principles of induction, already explained (page 347), we may obtain secure conclusions as to the nature of the country from whence those spoils were derived, of the animals by which it was inhabited, and of the vegetables that covered its surface.

* See a Memoir "On the Bones of Birds discovered in the Strata of Tilgate Forest," by the author: Geological Transactions, 1838.

That country must have been diversified by hill and dale, by streams and torrents, the tributaries of its mighty river. Arborescent ferns, palms, and yuccas, constituted its groves and forests; delicate ferns and grasses, the vegetable clothing of its soil; and in its marshes, equiseta, and plants of a like nature, prevailed. It was peopled by enormous reptiles, among which the colossal iguanodon and the megalosaurus were the chief. Crocodiles and turtles, flying reptiles and birds, frequented its fens and rivers, and deposited their eggs on the banks and shoals; and its waters teemed with lizards, fishes, and mollusca. But there is no evidence that Man ever set his foot upon that wondrous soil, or that any of the animals which are his contemporaries found there a habitation: on the contrary, not only is evidence of their existence altogether wanting, but from numberless observations made in every part of the globe, there are conclusive reasons to infer, that man and the existing races of animals were not created, till myriads of years after the destruction of the iguanodon country—a country, which language can but feebly portray, but which the magic pencil of a Martin, by the aid of geological research, has rescued from the oblivion of the past, and placed before us in all the hues of nature, with its appalling dragon-forms, its forests of palms and tree-ferns, and the luxuriant vegetation of a tropical clime.*

* See the Frontispiece; an engraving on steel, from an original painting by John Martin, Esq., K.L.

64. Sequence of geological changes.—Let us now review the sequence of those stupendous changes, of which our examination of the geological phenomena of the south-east of England has afforded such incontrovertible evidence. From the facts brought before us, we learn that at a period incalculably remote, there existed in the northern hemisphere an extensive island or continent, possessing a climate of such a temperature, that its surface was clothed with coniferous trees, arborescent ferns, and plants allied to the cycas and zamia; and that the ocean which washed its shores was inhabited by turtles and reptiles of extinct genera. This island and its forests suffered a partial subsidence, which was effected in such manner that many of the trees, although torn and rent, still retained their erect position; and the zamiæ, and a considerable layer of the vegetable mould in which they grew, remained undisturbed. In this state an inundation of fresh-water covered the once flourishing forest, and deposited upon the soil and around the trees a calcareous mud, which gradually consolidated into fine limestone; water, holding flint in solution, percolated through the mass, and silicified the now submerged trees and plants. A further depression took place — a body of fresh water, brought down by land-floods and rivers, overwhelmed the petrified forest, and heaped upon it accumulations of debris, which their parent streams had washed away from the rocks over which they

had flowed. The country traversed by the rivers, like that of the submerged forest, enjoyed a tropical climate; it was clothed with palms, arborescent ferns, and plants allied to the yucca and the dracæna, and tenanted by enormous reptiles, crocodiles, and land and fresh-water turtles; and in its waters were various kinds of fishes, mollusca, and aquatic plants. The bones and teeth of the reptiles—the remains of the turtles—the teeth and scales of fishes—the shells of the snails and muscles—the stems, leaves, and even seed-vessels, of the trees, were carried down by the stream, and deposited in the mud of the delta, beneath which the petrified forest was now buried. This state continued for a long period: another change took place; the country and its inhabitants were swept away, and the delta, and the strata on which it reposed, were submerged to a great depth, and formed part of the bottom of a profound ocean, whose waters teemed with myriads of zoophytes, shells, and fishes, of species that are now no more. Thermal waters, holding calcareous and silicious matter in solution, were poured into its basin, and, in its tranquil depths, layers of flint and chalk were deposited. And so rapidly were these changes effected, that fishes, while in the act of swimming, were arrested in their progress, and became suddenly enveloped in a bed of rock. This epoch was of considerable duration: at length elevatory movements began to take place, the bottom of the deep was slowly up-heaved, and as the elevation continued, the depositions which had formed in the basin of the ocean, and had become consolidated, were broken up, and as they approached the surface were acted upon by the waves. The chalk strata now began to suffer degradation and destruction, and the delta of the country of the iguanodon emerged above the waters; and finally, even the ancient petrified forest was brought to view, and became dry land. At length some masses rose to an elevation of a few hundred feet above the level of the sea, and formed a group of islands; but, in the depressions of the strata beneath the waters, deposits went on, from the waste of the cliffs on the sea-shores. Large mammalia now inhabited such portions of the former ocean-bed as were clothed with vegetation, and as they died their skeletons were enveloped in the accumulations of mud and gravel which were forming in the bays and estuaries. This era also passed away—the elevation continued—other portions of the bed of the chalk-ocean became dry land—and at length also those newer strata, in which the remains of the mammoth and the elk, the last tenants of the country, were entombed. The oak, elm, ash, and other trees of modern Europe, sprang up where the palms and tree-ferns once flourished; the deer, boar, and horse, ranged where the mighty reptiles once ruled sole monarchs of the country; and lastly, man appeared, and took possession of the soil. At the present time, a city* stands on the deposits which contain the remains of the elephant and the elk; the huntsman courses, and the shepherd tends his flocks, on the elevated and rounded masses of the bottom of the ancient chalk-ocean;† the farmer reaps his harvests upon the cultivated soil of the delta of the iguanodon;‡ and the architect seeks, beneath the petrified forest, for the materials with which to construct his edifices.

65. RETROSPECT OF GEOLOGICAL MUTATIONS.—Such is a plain enunciation of the results of our investigations; but I will embody these inductions in a more impressive form, by employing the metaphor of an Arabian writer, and imagining some higher intelligence from another sphere, to describe the physical mutations of which he may be supposed to have taken cognizance, from the period when the forests of Portland were flourishing, to the present time. Countless ages ere man was created, he might say, I visited these regions of the earth, and beheld a beautiful country of vast extent, diversified by hill and dale, with its rivulets, streams, and mighty rivers, flowing through fertile plains. Groves of palms and ferns, and forests of coniferous trees, clothed its surface; and I saw monsters of the reptile tribe, so huge that nothing among the existing races can compare with them, basking on the banks of its rivers and roaming through its forests;

* Brighton. † The South Downs.
‡ The wealds of Kent and Sussex.

while, in its fens and marshes, were sporting thousands of crocodiles and turtles. Winged reptiles of strange forms shared with birds the dominion of the air, and the waters teemed with fishes, shells, and crustacea. And after the lapse of many ages I again visited the earth; and the country, with its innumerable dragon-forms, and its tropical forests, all had disappeared, and an ocean had usurped their place. And its waters teemed with nautili, ammonites, and other cephalopoda, of races now extinct; and innumerable fishes and marine reptiles. And thousands of centuries rolled by, and I returned, and, lo! the ocean was gone, and dry land had again appeared, and it was covered with groves and forests; but these were wholly different in character from those of the vanished country of the iguanodon. And I beheld, quietly browsing, herds of deer of enormous size, and groups of elephants, mastodons, and other herbivorous animals of colossal magnitude. And I saw in its rivers and marshes the hippopotamus, tapir, and rhinoceros; and I heard the roar of the lion and the tiger, and the yell of the hyena and the bear. And another epoch passed away, and I came again to the scene of my former contemplations; and all the mighty forms which I had left had disappeared, the face of the country no longer presented the same aspect; it was broken into islands, and the bottom of the sea had become dry land, and what before was dry land had sunk beneath the waves. Herds of deer were still to be seen on the plains, with swine, and horses, and oxen; and wolves in the woods and forests. And I beheld human beings, clad in the skins of animals, and armed with clubs and spears; and they had formed themselves habitations in caves, constructed huts for shelter, inclosed pastures for cattle, and were endeavouring to cultivate the soil. And a thousand years elapsed, and I revisited the country, and a village had been built upon the sea-shore, and its inhabitants supported themselves by fishing; and they had erected a temple on the neighbouring hill, and dedicated it to their patron saint. And the adjacent country was studded with towns and villages; and the downs were covered with flocks, and the valleys with herds, and the corn-fields and pastures were in a high state of cultivation, denoting an industrious and peaceful community. And lastly, after an interval of many centuries, I arrived once more, and the village was swept away, and its site covered by the waves; but in the valley and on the hills above the cliffs a beautiful city appeared; with its palaces, its temples, and its thousand edifices, and its streets teeming with a busy population in the highest state of civilization; the resort of the nobles of the land, the residence of the monarch of a mighty empire. And I perceived many of its intelligent inhabitants gathering together the vestiges of the beings which had lived and died, and whose very forms were now obliterated from the face of the earth, and endeavouring, by these natural memorials, to trace the succession of those events of which I had been the witness, and which had preceded the history of their race.*

* The concluding portion of these remarks refers to the changes that have taken place on the Sussex coast, during the historical era. Before the Conquest, the greater part of the little fishing town of Brighthelmston (*Brighthelm's-town*), or Brighton, was situated below the cliffs, on a terrace of beach and sand, now covered by the waves. The Church, dedicated to St. Nicholas, the patron saint of fishermen, was placed on an eminence, that it might serve as a land-mark. The inroads of the sea led to the erection of buildings on the high ground, and its progressive encroachment gradually diminished the area of the ancient town, till at length a sudden inundation, but little more than a century ago, swept away the houses, fortifications, and inclosures, that remained.[a] The sea has, therefore, only resumed its former position at the base of the cliffs; the site of the old town having been an ancient bed of shingle, abandoned for ages by the ocean, perhaps contemporaneously with the retreat of its waters from the valley of the Ouse. Should the advancement of the sea be still progressive, Lewes Levels may again become an estuary, and the town of the *Cliff*, and the hamlet of *Landport*, regain the characters from which their names were derived. See page 45.

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[a] Illustrations of the Geology of Sussex, page 292. Geology of the South-East of England, page 23. Dallaway's Western Sussex, Vol. I. page 55.

# APPENDIX.

A. *Page* 21.—The surface of the moon.—The moon is the only planetary body placed sufficiently near us, to have the inequalities of its surface rendered distinctly visible with the telescope. Attendant on the earth, and having nearly the same density, we may reasonably infer that the mineral substances of which it is composed do not differ essentially from those on the surface of our own planet. Astronomers now generally admit that the moon is surrounded by a very clear atmosphere, but which is so low that it scarcely occasions a sensible refraction of the rays of light when it passes over the fixed stars. Many of the dark parts of the moon, particularly the part called *mare crisium*, appear to be covered with a fluid, which may probably be more transparent and less dense than water, as the form of the rocks and craters are seen beneath it, but not so distinctly as in the lighter parts of the moon's surface. To examine the moon with a reference to its external structure, the defining power of the telescope should be of the first quality, sufficient to show the projections of the outer illuminated limb as distinctly as they appear when the moon is passing over the disk of the sun during a solar eclipse. With such a telescope, and a sufficient degree of light and of magnifying power, almost every part of the moon's surface appears to be volcanic, containing craters of enormous magnitude and vast depth: the shelving rocks, and the different internal ridges within them, mark the stations at which the lava has stood and formed a floor during different eruptions; while the cones in some of the craters resemble those formed within modern volcanoes. The largest mountain on the southern limb of the moon, like the largest volcanic cone on the earth, Chimborazo, has no deep crater on its summit. There are indeed the outlines of the crater, but it is nearly filled up; while from the foot of this lunar mountain diverging streams of lava seem to flow in different directions, to the distance of six hundred miles. The longest known current of modern lava on the earth is in Iceland; it extends sixty miles; but the volcanoes in that island bear no proportion to those of the moon in magnitude.—*Mr. Bakewell.*

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B. *Page* 60.—The Lake of the Solfatara.—Its temperature was, in the winter, in the warmest parts, above 80 deg. of Fahrenheit, and it appears to be pretty constant; for I have found it to differ a few degrees only, in January, March, May, and the beginning of June; being nearly twenty degrees above the mean temperature of the atmosphere, it must therefore be supplied with heat from a subterraneous source. Kircher has detailed in his *Mundus Subterraneus* various wonders respecting this lake, most of which are unfounded, such as that it is unfathomable, that it has at the bottom the heat of boiling water, and that floating islands rise from the gulf. It must certainly be very difficult, or even impossible to fathom a source which rises with so much violence from a subterraneous excavation; and at a time when chemistry had made small progress, it was easy to mistake the disengagement of carbonic acid for an actual ebullition. The floating islands are real, but neither the Jesuit nor any of the writers who have since described this lake, have had a correct idea of their origin, which is exceedingly curious. The high temperature of this water, and the quantity of carbonic acid that it contains, render it peculiarly fitted to afford a pabulum or nourishment to vegetable life; the banks of travertine are every where covered with reeds, lichens, confervæ, and various kinds of aquatic vegetables. At the same time that the process of vegetable life is going on, the crystallization of the calcareous matter, which is every where deposited in consequence of the escape of carbonic acid, likewise proceeds, and gives a constant milkiness to what from its tint would otherwise be a blue fluid. So rapid is the vegetation, owing to the decomposition of the carbonic acid, that even in winter masses of confervæ and lichens, mixed with deposited travertine, are constantly detached by the currents of water from the bank, and float down the stream, which being a considerable river, is never without many of these small islands on its surface. They are sometimes only a few inches in size, and composed merely of dark green confervæ, or purple or yellow lichens; but, occasionally, are even several feet in diameter, and contain seeds and various species of common water-plants, which are usually more or less incrusted with marble. There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature, of the forces of inorganic chemical affinity, and those of the powers of life. Vegetables, in such a temperature, and every where surrounded by food, are produced with a wonderful rapidity; but the crystallizations are formed with equal quickness, and are no sooner produced than they are destroyed together. Notwithstanding the sulphureous exhalations from the lake, the quantity of vegetable matter generated there, and its heat, make it the resort of an infinite variety of insect tribes; and, even in the coldest days in winter, numbers of flies may be observed on the vegetables surrounding its banks, or on its floating islands. Their larvæ may also be seen there, sometimes incrusted and entirely destroyed by calcareous matter, as well as the insects themselves, and various species of shell-fish that are found amongst the vegetables which grow and are destroyed in the travertine on its banks. Snipes, ducks, and other water-birds, often visit these lakes, probably attracted by the temperature and the quantity of food in which they abound; but they usually confine themselves to the banks, as the carbonic acid disengaged from the surface would be fatal to them, if they ventured to swim upon it when tranquil. In May 18—, I fixed a stick on a mass of travertine covered by the water, and examined it in the beginning of the April following, for the purpose of determining the nature of the depositions. The water was lower at this time; yet I had some difficulty, by means of a sharp-pointed hammer, in breaking the mass which adhered to the bottom of the stick; it was several inches in thickness. The upper part was a mixture of light tufa and leaves of confervæ; below this was a darker and more compact travertine, containing black and decomposed masses of confervæ; in the inferior part, the travertine was more solid, and of a grey colour, but with cavities which I have no doubt were produced by the decomposition of vegetable matter. I have passed many hours, I may say days, in studying the phenomena of this wonderful lake; it has brought trains of thought into my mind connected with the early changes of our globe; and I have sometimes reasoned from the forms of plants and animals preserved in marble in this thermal source, to the grander depositions in the secondary rocks, where the zoophytes or coral insects have worked upon a grand scale, and where palms and vegetables, now unknown, are preserved with the remains of crocodiles, turtles, and gigantic extinct saurian animals, which appear to have belonged to a period when the whole globe possessed a much higher temperature. I have likewise often been led, from the remarkable phenomena surrounding me in that spot, to compare the works of man with those of nature. The baths, erected there nearly twenty centuries ago, present only heaps of ruins, and even the bricks of which they were built, though hardened by fire, are crumbled into dust; whilst the masses of travertine around, though formed by a variable source from the most perishable materials, have hardened by time, and the most perfect remains of the greatest ruins in the eternal city, such as the triumphal arches and the Colosseum, owe their duration to this source.

How marvellous are those laws by which the humblest types of organic existence are preserved, though born amidst the sources of their destruction, and by which a species of immortality is given to generations floating, as it were, like evanescent bubbles on a stream raised from the deepest caverns of the earth, and instantly losing what may be called its spirit in the atmosphere.—*Sir Humphrey Davy's Last Days of a Philosopher.*

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C. *Page* 62.—CAVERNS.—One of the most common appearances in limestone caverns, is the formation of what are called *stalactites,* from a Greek word signifying distillation, or dropping. To explain these, a brief description of the mode of their production will be necessary. Whenever water filters through a limestone rock, it dissolves a portion of it; and on reaching any opening, such as a cavern, either at its sides or roof, it forms a *drop*, the moisture of which is soon evaporated by the air, leaving a small circular *plate* of calcareous matter; another drop succeeds in the same place, and adds, from the same cause, a fresh coat of incrustation. In time, these successive additions produce a long, irregular, conical projection from the roof, which is continually being increased by the fresh accession of water loaded with calcareous or chalky matter, which it deposits on the outside of the *stalactite* already formed, and trickling down, adds to its length by subsiding to the point, and being dried up as before; precisely in the same manner as during frosty weather, icicles, which are *stalactites of ice*, or frozen water, are formed on the edges of the eaves of a roof. When the supply of water holding lime in solution is too rapid to allow of its evaporation at the bottom of the *stalactite*, it drops to the floor of the cave, and drying up gradually, forms, in like manner, a *stalactite* rising upwards from the ground, instead of hanging from the roof; these are called, for the sake of distinction, *stalagmites*.

It frequently happens, where these processes are uninterrupted, that a *stalactite* hanging from the roof, and a *stalagmite* formed immediately under it from the superabundant water, increase till they unite, and thus constitute a natural pillar, apparently supporting the roof of the grotto; it is to the grotesque forms assumed by stalactites, and these natural columns, that caverns owe the interesting appearances, described in such glowing colours by those who witness them for the first time.—*Saturday Magazine*, No. 42.

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D. *Page* 62.—Weyer's cave.—This cave is situated in a ridge of limestone hills, running parallel to the Blue mountains. A narrow and rugged fissure leads to a large cavern, where the most grotesque figures, formed by the percolation of water through beds of limestone, present themselves, while the eye, glancing onward, watches the dim and distant glimmers of the lights of the guides—some in the recess below, and others in the galleries above. Passing from these recesses, the passage conducts to a flight of steps that leads into a large cavern of irregular form, and of great beauty. Its dimensions are about thirty feet by fifty. Here the incrustations hang just like a sheet of water that has been frozen as it fell; there they rise into a beautiful stalactitic pillar, and yonder compose an elevated seat, surrounded by sparry pinnacles. Beyond this room is another, more irregular, but more beautiful. Besides having sparry ornaments in common with the others, overhead is a roof of the most admirable and singular formation. It is entirely covered with *stalactites*, which are suspended from it like inverted pinnacles. They are of the finest material, and are most beautifully shaped and embossed. In another apartment, an immense sheet of transparent *stalactite* extends from the roof to the floor, which, when struck, emits deep and mellow sounds, like those of a muffled drum. Farther on is another vaulted chamber, which is one hundred feet long, thirty-six wide, and twenty-six high. Its walls are filled with grotesque concretions. The effect of the lights placed by the guides at various elevations, and leaving hidden more than they reveal, is extremely fine. At the extremity of another range of apartments, a magnificent hall, two hundred and fifty feet long, and thirty-three feet high, suddenly appears. Here is a splendid sheet of rock-work, running up the centre of the room, and giving it the aspect of two separate and noble galleries; this partition rises twenty feet above the floor, and leaves the fine span of the arched roof untouched. There is here a beautiful concretion, which has the form and drapery of a gigantic statue; and the whole place is filled with stalagmitical masses of the most varied and grotesque character. The fine perspective of this room, four times the length of an ordinary church, and the amazing vaulted roof spreading overhead, without any support of pillar or column, produces a most striking effect. In another apartment, which has an altitude of fifty feet, there is at one end an elevated recess, ornamented with a group of pendant *stalactites* of unusual size, and singular beauty. They are as large as the pipes of a full-sized organ, and ranged with great regularity; when struck, they emit mellow sounds of various keys, not unlike the tones of musical glasses. Other cavities, profusely studded with sparry incrustations, extend through the limestone rock. The length of this extraordinary group of caverns is not less than one thousand six hundred feet.—*Abridged from "A Narrative of the Visit to the American Churches," by Drs. Reed and Matheson.*

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E. *Page* 80.—Recent formation of sandstone.—"A sandstone occurs in various parts of the northern coast of Cornwall, which affords a most instructive example of a recent formation; since we here actually detect Nature at work in converting calcareous sand into stone. A very considerable portion of the northern coast of Cornwall is covered with a calcareous sand, consisting of minute particles of comminuted shells, which, in some places, has accumulated in quantities so great, as to have formed hills of from forty to sixty feet in elevation. In digging into these sand hills, or upon the occasional removal of some part of them by the winds, the remains of houses may be seen: and in some places, when the churchyards have been overwhelmed, a great number of human bones may be found. The sand is supposed to have been originally brought from the sea by hurricanes, probably at a remote period. At the present moment, the progress of its incursion is arrested by the growth of the *arundo arenacea.* The sand first appears in a slight but increasing state of aggregation on several parts of the shore in the Bay of St. Ives; but, on approaching the Gwythian river, it becomes more extensive and indurated. On the shore opposite Godrevy Island, an immense mass of it occurs, of more than a hundred feet in length, and from ten to twenty in depth, containing entire shells and fragments of clay-slate; it is singular that the whole mass assumes a striking appearance of stratification. In some places, it appears that attempts have been made to separate it, probably for the purpose of building, for several old houses in Gwythian are built of it. The rocks in the vicinity of this recent formation in the Bay of St. Ives, are greenstone and clay slate, alternating with each other. The clay slate is in a state of rapid decomposition, in consequence of which large masses of the hornblende rock have fallen in various directions, and given a singular character of picturesque rudeness to the scene. This is remarkable in the rocks which constitute Godrevy Island. It is around the promontory of New Kaye, that the most extensive formation of sandstone takes place. Here it may be seen in different stages of induration, from a state in which it is too friable to be detached from the rock upon which it reposes, to a hardness so considerable that it requires a very violent blow from a sledge to break it. Buildings are here constructed of it; the church of Cranstock is entirely built with it; and it is also employed for various articles of domestic and agricultural uses. The geologist who has previously examined the celebrated specimen from Guadaloupe, will be struck with the great analogy which it bears to this formation. Suspecting that masses might be found containing human bones, if a diligent search were made in the vicinity of those cemeteries which have been overwhelmed, I made some investigations in those spots, but, I regret to add, without success. The rocks upon which the sandstone reposes, are alternations of clay slate, and slaty limestone. The inclination of the beds is SS.W., and at an angle of 40°. Upon a plane formed by the edges of these strata, lies a horizontal bed of rounded pebbles, cemented together by the sandstone which is deposited immediately above them, forming a bed of from ten to twelve feet in thickness, and containing fragments of slate, and entire shells; and exhibiting the same appearance of stratification as that noticed in St. Ives Bay. Above this sandstone lie immense heaps of drifted sand. But it is on the western side of the promontory of New Kaye, in Fishel Bay, that the geologist will be most struck with this formation; for here no other rock is in sight. The cliffs, which are high, and extend for several miles, are entirely composed of it; they are occasionally intersected by veins and dykes of breccia. In the cavities, calcareous stalactites of rude appearance, opaque, and of a grey colour, hang suspended. The beach is covered with disjointed fragments, which have been detached from the cliffs above, many of which weigh two or three tons."—*From the Transactions of the Royal Geological Society of Cornwall, by Dr. Paris.*

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F. *Page* 95.—LITHODOMI, OR BORING MOLLUSCA; *which have the power of perforating rocks.*—Every one who has walked by the sea-side must have observed the blocks and masses of the chalk rocks full of perforations; and if his curiosity have induced him to examine these with attention, he will have perceived that though many of the cavities are empty, some of them contain the shelly remains of the animals which once inhabited them. The power possessed by creatures so delicate, and with such fragile coverings, of excavating the solid rock, has naturally excited much speculation as to the mode by which the perforations are effected; and it is now generally admitted, that it is not by mechanical power only that the feeble inhabitants of the boring shells are able to form themselves a secure asylum in the rock, but by the secretion of a liquid which acts chemically on the stone, softens it, and renders it capable of being removed with facility. In a late volume of the Philosophical Transactions, there is an interesting paper on the economy of molluscous animals, by Mr. Gray, which throws much light on the subject. It appears that, although *teredines*, *pholades*, and other boring shells, are covered with short spines and striæ, by means of which they were supposed capable of rasping stones, yet other mollusca which inhabit stony cavities are perfectly smooth. On the shore, near Kemptown, a *pholas*, which has a rasping apparatus, and a *venus*, wholly destitute of a rugous surface, may be seen in cavities of the chalk. Shells of this kind have not been observed to bore into any other substances (wood excepted) than shells, marl, chalk, limestone, and sandstone, consolidated by calcareous cement. Granite appears to resist all the dissolving powers of the mollusca. Thus, in the Plymouth Breakwater, in which limestone and granite are employed and placed side by side, the *patellæ*, or limpets, form their rounded holes in the former, while they do not in the slightest degree alter the surface of the latter, except by clearing off from it any adherent calcareous substance.

G. *Page* 96.—Observations on the Temple of Serapis, at Puzzuoli, near Naples; *in a Letter to W. H. Fitton, M.D., from Charles Babbage, Esq.*—This paper commences with a general description of the present state of the Temple of Serapis, and gives the measurement of the three marble columns which remain standing, and which, from the height of eleven feet to that of nineteen, are perforated on all sides by the *modiola lithophaga* (of Lamarck); the shells of that animal remaining in the holes formed by them in the columns. A description follows of the present state of twenty-seven portions of columns, and other fragments of marble, and also of the several incrustations formed on the walls and columns of the temple.

From these and other data, Mr. Babbage concludes:—

1. That the temple was originally built at, or nearly at the level of the sea, for the convenience of sea-baths, as well as for the use of the hot spring which still exists on the land side of the temple.

2. That, at a subsequent period, the ground on which the temple stood, subsided slowly and gradually; the salt water, entering through a channel which connected the temple with the sea, or by infiltration through the sand, mixed itself with the water of the hot spring containing carbonate of lime, and formed a lake of brackish water in the area of the temple, which, as the land subsided, became deeper, and formed a dark incrustation.

The proofs are, that sea-water alone does not produce a similar incrustation; and that the water of the hot spring alone produces an incrustation of a different kind; also, that serpulæ are found adhering to this dark incrustation; and that there are lines of water-level at various heights from 2.9 feet to 4.6 feet.

3. The area of the temple was now filled up to the height of about seven feet with ashes, tufa, or sand, which stopped up the channel by which sea-water had been admitted. The waters of the hot spring thus confined, converted the area of the temple into a lake, from which an incrustation of carbonate of lime was deposited on the columns and walls. The proofs are, that the lower boundary of this incrustation is irregular; whilst the upper is a line of water-level, and that there are many such lines at different heights;—that salt water has not been found to produce a similar incrus-

tation;—that the water of the Piscina Mirabile, which is distant from the sea, but in this immediate neighbourhood, produces, according to an examination by Dr. Faraday, a deposit almost precisely similar;—that no remains of serpulæ, or other marine animals, are found adhering to it.

4. The temple continuing to subside, its area was again partially filled with solid materials; and at this period was subjected to a violent incursion of the sea. The hot-water lake was filled up, and a new bottom produced, entirely covering the former, and concealing also the incrustation of carbonate of lime.

The proofs are, that the remaining walls of the temple are highest on the inland side, and decrease in height towards the sea-side, where they are lowest;—that the lower boundary of the space perforated by the marine *lithophagi* is, on different columns, at different distances beneath the uppermost, or water-level line;—that several fragments of columns are perforated at the ends.

5. The land continuing to subside, the accumulations at the bottom of the temple were submerged, and modiolæ attaching themselves to the columns and fragments of marble, pierced them in all directions. The subsidence continued until the pavement of the temple was at least nineteen feet below the level of the sea.

The proofs are derived from the condition of the columns and fragments.

6. The ground on which the temple stood, appears now to have been stationary for some time, but it then began to rise. A fresh deposition of tufa, or of sand, was lodged, for the third time, within its area, leaving only the upper part of three large columns visible above it.

Whether this took place before or subsequently to the rise of the temple to its present level, does not appear; but the pavement of the area is at present level with the waters of the Mediterranean.

The author then states several facts, which prove that considerable alterations in the relative level of the land and sea have taken place in the immediate vicinity. An ancient sea-beach exists near Monte Nuovo, two feet above the present beach of the Mediterranean. The broken columns of the Temples of the Nymphs and of Neptune, remain at present standing in the sea. A line of perforations of modiolæ, and other indications of a water-level four feet above the present sea, are observable on the sixth pier of the bridge of Caligula; and again on the twelfth pier, at the height of ten feet. A line of perforations by modiolæ is visible in a cliff opposite the island of Nisida, thirty-two feet above the present level of the Mediterranean.—*Abstract of the Proceedings of the Geological Society; March*, 1834.

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H. *Page* 325.—Mr. Reade's recent observations on fossil infusoria are embodied in Lecture VI. See also *Appendix* N and O.

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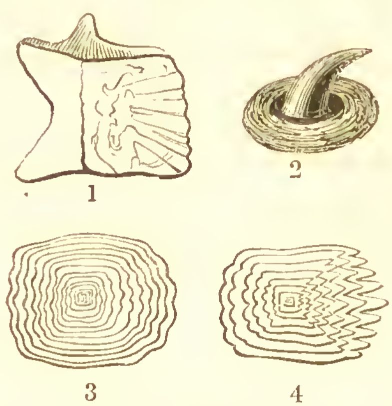
I. *Page* 328.—AGASSIZ'S CLASSIFICATION OF FISHES.




TAB. 84.—SCALES OF THE FOUR ORDERS OF FISHES, AS DETERMINED BY M. AGASSIZ.

1. Scale of a *Ganoid* order—of *Lepidotus*.
2. ,, *Placoid* order—of *Ray*.
3. ,, *Cycloid* order—of *Salmon*.
4. ,, *Ctenoid* order—of *Beryx*.

K. *Page* 339.—A TABULAR ARRANGEMENT OF THE FOSSIL FISHES OF THE CHALK FORMATION OF THE SOUTH-EAST OF ENGLAND, COLLECTED BY GIDEON MANTELL, LL.D. F.R.S.; IN THE MANTELLIAN MUSEUM AT BRIGHTON.*

*(From "Recherches sur les Poissons Fossiles," by M. Agassiz.)*

"Tout le monde sait que le Musée de M. le Dr. Mantell à Brighton est une collection classique pour la craie, et la formation Veldienne. Les soins minutieux que M. Mantell a donnés depuis bien des années à ces fossiles, les ont rendus plus parfaits que tous ceux des autres musées; car souvent il est parvenu à les detacher entièrement de la roche dans laquelle ils se trouvaient; ou du moins à les produire en relief, en détachant toutes les matières solides qui recouvraient les parties les mieux conservees de l'animal."

ORDER I.—The *Placoidians*, (from πλαξ, a broad plate.) The skin, covered irregularly with enamelled plates, sometimes of a large size, but frequently in the form of small points, as in the shagreen on the skin of sharks, and the tubercles on the integuments of rays. Tab. 84, fig. 2.

PTYCHODUS *latissimus*. Mantell's South Down Fossils. Tab. xxxii. fig. 19. Agassiz, Poiss. Foss. Vol. iii. tab. 25.
———— *polygyrus*. Ibid. Tab. xxxii. figs. 23, 24.
———— *mammillaris*. Ibid. Tab. xxxii. figs. 18, 20, 25, 29.
———— *decurrens*. Tab. 58, fig. 6, page 329.
———— *altior*. South Down Fossils. Tab. xxxii. figs. 17, 21, 27.

Teeth, and perhaps vertebræ, of the above species, and a few examples of their dorsal defences, (*Ichthyodorulites* of Dr. Buckland,) are the only remains hitherto discovered. (*Agass. Poiss. Foss.* Vol. iii. tab. $10^a$, $10^b$.) The teeth were referred to fishes of the genus Diodon, by previous authors, and the defences were called radii, or fin-bones of balistes, and siluri.

Teeth of a new species of *Ptychodus* have been discovered in the sand of New Jersey, United States, by Dr. Morton.—(*Morton's Synopsis*, Pl. 18, fig. 1, 2.) I have named it *Ptychodus Mortoni*.

PTYCHODUS,—*spec. undetermined*. Dorsal defences, and a beautiful example of a fin, are represented in the Fossils of the South Downs. Tab. xxxiv. fig. 8. Tab. xxxix. and Tab. xl. fig. 3.
GALEUS *pristodontus*. Tab. 58, fig. 3. South Down Fossils. Tab. xxxii. figs. 12 to 16. Agass. Poiss. Foss. Vol. iii. tab. xxvi. fig. 14.
NOTIDANUS *microdon*. Tab. 58, fig. 1, page 329. Agass. Tab. xxxii. fig. 22.
LAMNA *appendiculata*. Tab. 58. fig. 4, page 329. Agass. Tab. xxxii. figs. 2, 3, 5, 6. 9.
———— *acuminata*. Agass. Tab. xxxii. fig. 1.

* Now in the British Museum.

LAMNA *Mantellii*. Tab. 58, fig. 2, page 329. Agass. Tab. xxxii. figs. 4, 7, 8, 10.
———— *crassissima*. Not figured.
ODONTAPSIS *raphiodon*. Not figured.
SPINAX *major*. Agass. Poiss. Foss. Vol. iii. tab. 10, figs. 8, 14.
PSAMMODUS *asper*. Poiss. Foss. Vol. iii. tab. 10, figs. 1, 3.
ACRODUS *transversus*. Poiss. Foss. Vol. iii. tab. 10, figs. 4, 5.
GYRODUS *angustus*. Poiss. Foss. Vol. ii. tab. 66a, figs. 14, 15.

The above order of fishes is represented by five genera, of which one, containing twelve species, is extinct. The fishes of the genera Ptychodus, Galeus, and Lamna, are very widely distributed.

ORDER II.—The *Ganoidians*,—(γανος, splendour, from the brilliant surface of their enamel.) These are characterised by angular scales, formed of horny or bony plates, protected by a thick layer of enamel. Tab. 84, fig. 1.

MACROPOMA *Mantellii*. Tab. 61, page 334. Length 24 inches. South Down Fossils. Tab. xxxvii. and xxxviii. Agass. Poiss. Foss. Vol. v. tab. 60b, fig. 2.
———————— Coprolites of: South Down Fossils. Tab. ix. figs. 5, 11. Agass. Poiss. Foss. Vol. ii. tab. 65.

The Macropoma is perhaps the most remarkable of all the fossil fishes; in most examples the membranes of the stomach are preserved.

SPHŒRODUS *mammillaris*. Not figured. From Clayton chalk-pit.
DERCETIS *elongatus*. Tab. 62, page 335. Length 16 inches. South Down Fossils. Tab. xxxiv. figs. 10, 11. Tab. xl. fig. 2. Agass. Poiss. Foss. Vol. ii. tab. 66a, figs. 1 to 8.

The above order comprehends three extinct genera, with three species. Another species of *Dercetis* has been found in the chalk of Westphalia.

ORDER III.—The *Ctenoïdians*, (κτεις, a comb.) The scales of this order are pectinated on their posterior margin, like the teeth of a comb, and are composed of laminæ of horn or bone, but have no enamel. Tab. 84, fig. 4.

BERYX *Lewesiensis*. (B. ornatus of Agassiz.) Tab. 64, page 337. Length 12 inches. South Down Fossils. Tab. xxxiv. fig. 6. Tab. xxxv. Tab. xxxvi. Agass. Poiss. Foss. Vol. iv. tab. 14a.
——— *radians*. Tab. 63, page 336. Length 7 inches. History of the County of Sussex. Vol. ii. Part ii. p. 15, fig. 22. Agass. Poiss. Foss. Vol. iv. tab. 14b, fig. 7.
——— *microcephalus*. Agass. Poiss. Foss. Vol. iv. tab. 4c, figs. 7 to 9.

There are other species of Beryx in the chalk of Bohemia and Westphalia; and genera nearly related to *Beryx*, in the schist of Glaris. In England this order contains but three species of a genus, of which we know but one living species.

ORDER IV.—The *Cycloïdians*, (κυκλος, a circle.) The scales smooth, with a simple margin, composed of laminæ of horn or bone without enamel. Tab. 84, fig. 3.

OSMEROIDES *Mantellii*. (*Salmo? Lewesiensis* of Mantell.) Tab. 60, page 333. Length 12 inches. South Down Fossils. Tab. xxx. fig. 12. Tab. xxxiv. fig. 3. Tab. xl. fig. 1. Agass. Poiss. Foss. Vol. v. tab. $60^{o}$.

To the above species belong the remarkable uncompressed specimens in my Museum.

OSMEROIDES *Lewesiensis*. Agass. Poiss. Foss. Vol. v. tab. $60^{c}$. (*Salmo? Lewesiensis* of Mantell.) This species is more elongated than *O. Mantellii*, and the number of rays in the dorsal fin is greater.

———— *granulatus*. History of Lewes. Vol. i. plate xxix. fig. 13. The bones of the head, with the jaws and teeth, have alone been discovered. Agass. Poiss. Foss.

ENCHODUS *halocyon*. South Down Fossils. Tab. xxxiii. figs. 2, 3, 4. Tab. xliv. figs. 1, 2. Agass. Poiss. Foss. Vol. v. tab. 25. figs. 11 to 6.

SAUROCEPHALUS *lanciformis*. (Harlan.) South Down Fossils. Tab. xxxiii. figs. 7, 6. Trans. Geol. Soc. of Pennsylvania, Vol. i. p. 83. Agass. Poiss. Foss. Vol. v. tab. 25, figs. 21 to 29.

SAURODON *Leanus*. (Hays.) Trans. American Philos. Society, vol. for 1830, plate 16. Agass. Poiss. Foss. Vol. v. tab. 25, figs. 17 to 20.

HYPSODON *Lewesiensis*. South Down Fossils. Tab. xxxiii. fig. 8. Tab. xlii. figs. 1 to 5. Agass. Poiss. Foss. Vol. v. tab. $25^{a}$.

From the resemblance of the teeth of this fish, to those of reptiles, it was supposed that the original belonged to an extinct genus of saurians; but in 1833, a considerable portion of the head, with the maxillæ, many vertebræ, &c., were discovered in a block of chalk, near Lewes, and the true characters of this remarkable ichthyolite determined.

*** The following fishes have been named by M. Agassiz, since the above table was constructed.

ACROGNATHUS *boops*. Tab. 60, page 333. Natural size. Agass. Poiss. Foss. Vol. iii. tab. $60^{a}$, figs. 1, 4. An unique specimen from Southerham quarry, near Lewes.

AULOLEPIS *typus*. Tab. 61, page 334. Length 6 inches. An unique specimen, from Clayton chalk-pit, Sussex. One nearly perfect example has alone been found. Poiss. Foss. Vol. iii. tab. 60, figs. 5, 8.
BELONOSTOMUS *cinctus*. Agass. Poiss. Foss. Vol. ii. tab. 66a, figs. 10 to 13.
CHIMERA *Agassizii*. Agass. Poiss. Foss. Vol. iii. pl. 40, figs. 3, 5. (Determined by Dr. Buckland.) The beaks or mandibles have alone been discovered.
——— *Mantellii*. Tab. 59, page 330. Agass. Poiss. Foss. Vol. iii. pl. 40, figs. 1, 2. Two mandibles were found, many years since, in a block of chalk, near Lewes. This species also occurs in the Shanklin sand of Kent. A beak has been found by Mr. W. H. Bensted in the iguanodon quarry, near Maidstone.
TETRAPTERUS *minor*. Lewes. Agass. Poiss. Foss. Vol. iii. tab. 60, figs. 1, 4.
CATURUS *similis*. Agass. Poiss. Foss. Vol. ii. tab. 66a, fig. 9.
ACROTEMNUS *faba*. Poiss. Foss. Vol. ii. tab. 66a, figs. 16, 18.

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L. *Page* 395.—MAIDSTONE IGUANODON.—This speeimen was purchased of Mr. Bensted in its broken state, and presented to Dr. Mantell by the following gentlemen of Brighton, the proposition originating with the two whose names stand first on the list, viz.—Horaee Smith, Moses Rieardo, Thomas Attree, George Basevi; Thomas Bodley, R. Heaviside, E. Lindo, J. J. Masquerier, W. Tenant, and T. Sarel, Esqrs.; Drs. Hall and Price; Revds. J. S. M. Anderson, Thomas Rooper, H. M. Wagner; and Sir Riehard Hunter.

END OF VOL. I.

RICHARD CLAY, PRINTER, BREAD STREET HILL.


FOSSIL CROCODILE DISCOVERED AT SWANAGE

## DESCRIPTION OF PLATE I.

*Remains of a Fossil Crocodile discovered at Swanage, by* ROBERT TROTTER, *Esq. F.G.S. of Borde Hill, near Cuckfield.*

Described pp. 387—389.

1. The left side of the lower jaw, with two teeth remaining in their natural position: fig. 10, Pl. III. represents one of these teeth on a larger scale.

2, 2. Detached vertebræ of the back and tail, showing the transverse and dorsal processes.

3, 3. Dermal, or skin-bones: in the living animal these are disposed in parallel rows along the spinal column, like a ridge of roof-tiles, and are designed to support the large scales.

4, 4. Ribs, more or less broken.

5. Two chevron bones: these are inferior spinous processes articulated to the vertebræ of the tail. In a specimen of caudal vertebræ of the iguanodon, (Pl. III. fig. 8, *b*.) three processes of this kind, but differing in form from those before us, are seen lying beneath the vertebræ.

6, 7, 8. Bones of the pelvis.

6. One of the bones of the pelvis, detached; the corresponding bone is seen near the following.

7, 7. The bones of the ischium.

8. The remaining bones of the pelvis, attached to each other in their natural position.

Numerous scales and teeth of a fresh-water fish, (*lepidotus minor*,) peculiar to the Purbeck strata, are imbedded in the stone.

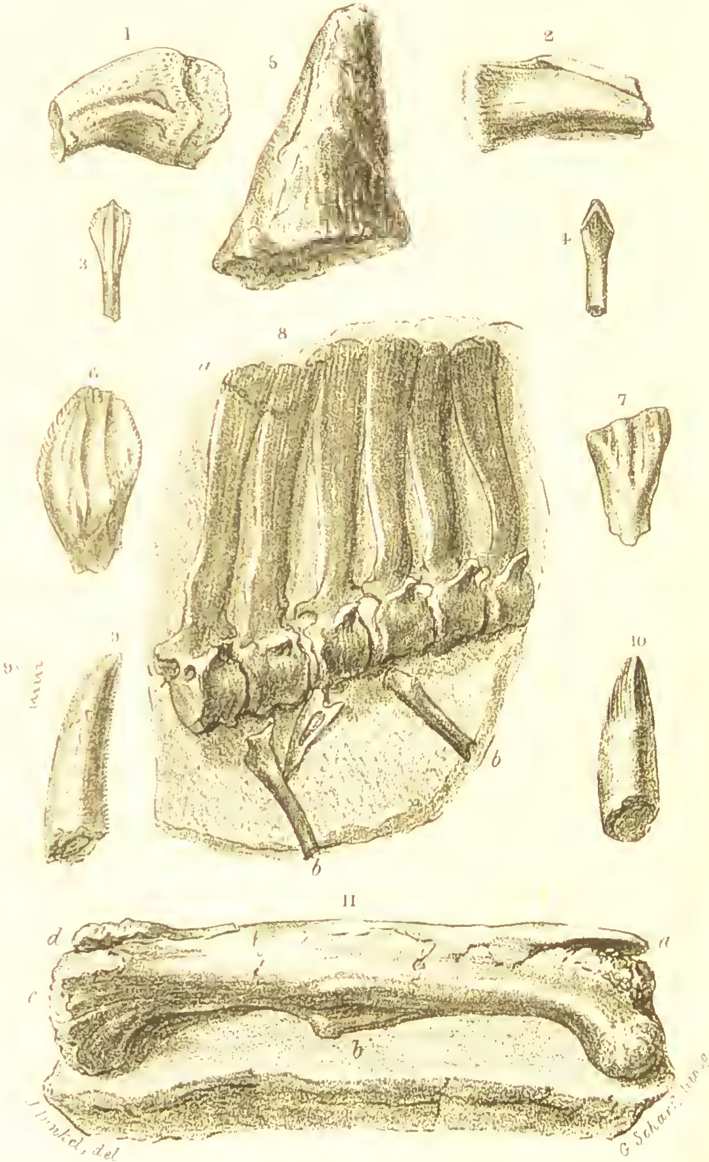

IGUANODON DISCOVERED NEAR MAIDSTONE

## DESCRIPTION OF PLATE II.

*The Remains of the Iguanodon discovered by Mr. W. H. Bensted, in a Quarry of Kentish Rag, near Maidstone.*

Described pp. 394—397.

1, 2. The right and left thigh-bone, or *femur.*
3. A leg-bone, or *tibia.*
4, 4, 4. Bones of the toes (*metatarsal* and *phalangeal*) of the hind feet.
5, 5. Two *unguical,* or claw-bones of the hind-foot.
6. Two *metacarpal,* or finger bones of the fore-foot.
7. One of the bones (*radius*) of the fore-arm.
8' 8, 8. Vertebræ of the back and tail: in the upper part of the specimen a series of eight vertebræ remains.
9, 9, 9. Ribs: some nearly entire, others broken.
10, 10. Two clavicles, or collar-bones.
11, 11. Two bones of the pelvis (*ossa ilia*).
12. A *chevron-bone,* or inferior spinous process of the tail.




REMAINS OF REPTILES FROM TILGATE FOREST.

## DESCRIPTION OF PLATE III

*Remains of Reptiles from the strata of Tilgate Forest.*

1. One of the claw-bones of the fore-foot of the iguanodon. See p. 397.
2. One of the claw-bones of the hind-foot of the Maidstone iguanodon. See p. 397.
3. Perfect tooth of the iguanodon, one-third the natural size. See p. 390.
4. Inner surface of a tooth of an unknown reptile. See p. 403.
5. Horn of the iguanodon. See p. 400.
6. Tooth of the iguanodon; the crown slightly worn by use, and the fang absorbed from pressure of the new tooth; half the natural size. See p. 390.
7. Tooth of the iguanodon, much worn; the serrated edges being entirely obliterated; half the natural size. This is the individual specimen which M. Cuvier mistook for an incisor tooth of the rhinoceros, until a series of specimens was obtained, showing a gradual transition from the perfect to the worn tooth.
8. Six vertebræ of the tail of an iguanodon, articulated to each other, having their spinous (*a*) and transverse processes remaining; and three chevron-bones (*b b*) imbedded in the stone near the vertebræ. From Cuckfield, by R. Trotter, Esq. See p. 399.
9. Tooth of the megalosaurus, one-third the natural size. 9*. Magnified view of the serrated edge of the tooth. See p. 389.
10. Tooth of the Swanage crocodile. See p. 388.
11. The right femur, or thigh-bone, of an iguanodon, imbedded in limestone; from Tilgate Forest (pp. 395—398). The original was 3 feet 8 inches in length. *a*, the large process (*trochanter major*), on the upper and outer part of the bone; *b*, the inner process (*trochanter minor*), for the attachment of adductor muscles, by which the limbs were drawn towards each other; *c*, the inner condyle; *d*, the groove in front of the condyles, for the passage of a tendon to be inserted into the leg-bone.

Pl. IV

J. Dinkel, del. G. Scharf. lithog.

HYLÆOSAURUS FROM TILGATE FOREST

## DESCRIPTION OF PLATE IV.

*Remains of the Hylæosaurus, discovered in Tilgate Forest.*

Described pp. 401, 402.

(Size of the original specimen, four and a half feet in length.)

This plate represents the extraordinary and highly interesting fossil discovered in Tilgate Forest, by the Author, in the summer of 1832. The speeimen exhibits the anterior or upper portion of the skeleton of an extinet reptile, the *hylæosaurus*, or fossil lizard of the weald.

1. Vertebræ of the neck, or *cervical.*
2. Vertebræ of the baek, or *dorsal.*
3. Ribs, for the most part perfect, and but little removed from their articulation with the vertebræ.

4, 4. Angular or spinous proeesses.

5. Three very large spinous or angular processes; each 15 inches in length.

6, 6. Two *coracoid* bones (belonging to the ehest).

7, 7. The two *omoplates*, or scapulæ.